

AN INNOVATIVE AND SUSTAINABLE ODOUR MANAGEMENT SOLUTION AT THE GIPPSLAND WATER FACTORY

Sean Trainor¹, Josef Cesca¹, Jay Witherspoon¹, Marilyn Olliff² and Simon Aquilina³

¹CH2M HILL Australia Pty Ltd, Sydney, NSW

²Parson's Brinckerhoff, Melbourne, VIC

³Gippsland Water, Traralgon, VIC

ABSTRACT

This paper outlines the odour management solution at Gippsland Water Factory, which uses innovative biological technologies to treat waste with extremely high odour potential. The design uses a combination of activated sludge bioreactors, multistage biological trickling filters and a 25m high stack to comply with some of the most stringent odour impact requirements in the world. This design will ensure that odour impacts at the plant boundary will be less than 3 OU on a 99.9 percentile basis. Furthermore, the biological technologies used have been shown to effectively treat extremely high contaminant concentrations without the need for chemicals and with no off-site wastes.

The paper will also discuss some of the many challenges of the project during the design, construction and commissioning preparation phases. It will include details of the specified performance of the bio-trickling filters discuss the cover design of bioreactors; and the control philosophy to manage the air extraction system.

Construction of the Gippsland Water Factory is expected to be completed early 2009 and will make this sustainable odour management vision a reality.

INTRODUCTION

The Gippsland Water Factory (GWF) is a new wastewater treatment and recycling system currently being constructed in Gippsland, Victoria. The treatment plant is being built at Maryvale near Morwell. Odour management at the plant will be achieved through the installation of innovative biological technologies capable of treating air with high odour potential.

This paper will provide some background regarding the plant and the foul air to be treated, and outline the rationale behind the design of the odour management system. The expected odour emissions upon treatment of air in activated sludge bioreactors and bio-trickling filters will be presented; along with the results of odour sampling undertaken during the pilot plant trial of the GWF activated sludge bioreactors. Some of the challenges of the project will also be discussed, including construction challenges and the control philosophy to manage the system.

As well as being an innovative solution that ensures the local community is not affected by odour, the odour management system at GWF is more sustainable than odour control systems installed elsewhere, as pre-treatment is achieved through the activated sludge bioreactors, decreasing the size of the bio-trickling filter system required. The bio-trickling filter system removes odours from discharged air using biological processes, rather than relying on chemicals

BACKGROUND

GWF will be an innovative wastewater treatment and recycling system located in the Gippsland region of Victoria. It will deliver a range of benefits to the community and environment, but most significantly will address the odour from the open channel section of the Regional Outfall Sewer (ROS), which currently carries untreated wastewater - predominantly industrial wastewater from a large Kraft pulp mill - more than 40km to sea, after it first travels the same distance in a pipeline.

The wastewater coming from the pulp mill is very high in sulphates. This, combined with the high

biological oxygen demand (BOD) of the wastewater, results in significant sulphide generation (>100mg/L) in the pipeline section of the ROS. When the wastewater reaches the open channel section, these sulphides are released as H₂S and other reduced sulphide compounds, creating a major odour source. The key driver for GWF is to solve this odour problem by diverting the wastewater to a treatment facility prior to it entering the ROS, so only highly treated wastewater, free of odour causing organics then flows down the sewer.

It is important that the process of eliminating this odour source does not create new sources of odour. Therefore, an odour collection and treatment system needs to be installed at the GWF treatment plant itself.

AUSPLUME odour dispersion modelling was undertaken, as per Victorian legislation, to determine the odour impact of the GWF on the surrounding area. This modelling and an associated risk assessment indicated that the design was sufficient to ensure it was unlikely there would be any adverse odour impact on the community from GWF.

Figure 1 shows a process flow diagram of the GWF plant.

To ensure that odour is minimised, all sources of odour at GWF need to be contained and treated. These include:

- Highly odorous - Primary screening, grit processing, and grit and screenings handling systems, Flow balance tank, activated primary sedimentation tank (APST) and combined pump station.
- Potentially significant odours - Sludge dewatering plant and Industrial membrane bioreactor (IMBR).
- Low level odours - Domestic membrane bioreactor (DMBR).
- Biogas from the covered anaerobic reactor is biologically scrubbed and used in a cogeneration facility.

The air flow to be treated from each of these process units is shown in Table 1 below.

Table 1 Air flows to be treated

PROCESS	FLOW (M ³ /HR)
Inlet works	4450
Flow balance tank	1,000
APST	3200
Pump stations	1100
Dewatering facilities	18,900
DMBR	13363
IMBR	35335
TOTAL FLOW	48700

The actual membrane cells of the membrane bioreactors (MBR) do not require covering as odour measurement of existing installations indicates they do not make a measurable impact on the overall odour. Also, covering these sections is operationally awkward.

The industrial wastewater entering the plant is high strength and nutrient deficient, with very high sulphate concentrations. Prior to treatment in the IMBR, the industrial wastewater is treated in an anaerobic process. This process converts the majority of the sulphates into sulphides, resulting in sulphide concentrations of greater than 200mg/L being fed to the IMBR. This was considered a very significant issue, as these sulphides could be released to the vapour phase in the aerated process as hydrogen sulphide (H₂S), creating a highly concentrated odour stream.

DESIGN OF THE ODOUR MANAGEMENT SOLUTION

From the various options available for the treatment of odour, the selected technology combination involves treatment of the foul air through the activated sludge bioreactors, followed by treatment in two-stage bio-trickling filters and discharge via a 25m stack. (Trainor et al. 2008).

This odour management solution is innovative and considered a sustainable solution. The media life in the bio-trickling filters is greater than 10 years, which is higher than for activated carbon systems or biofilters, and the system does not rely on the use of chemicals to treat odours.

Additionally, by treating foul air in the MBRs prior to the bio-trickling filters; the size of the system required has been reduced for two reasons. The volume of air requiring treatment in the bio-trickling filters is reduced because a portion is first treated in the activated sludge reactors. This treatment in the reactors reduces the emission concentration.

ACTIVATED SLUDGE PROCESS

GWF Pilot Plant Testing

As part of the GWF project, a pilot plant was constructed and operated. The pilot plant was designed to represent the industrial stream of the full-scale plant, at a scale of 1:1000. The process consisted of a 35,000L anaerobic pre-treatment, followed by a 28,600L diffused air bioreactor and a membrane zone. The MBR was operated to maintain a specified solids residence time (SRT) of 12 to 18 days and a bioreactor dissolved oxygen (DO) set point of 2mg/L (Daigger et al. 2007).

Emission testing at the pilot plant was conducted by EML Pty Ltd in September 2007 (EML Air, 2007). Samples were collected from the activated sludge bioreactor at the start of the aeration cycle, as this was considered to be the time in the cycle when odour emissions were at their worst. Sampling was undertaken in accordance with the USEPA 600/8-86/008. This method utilises a flux hood with a surface area of 0.1257m² and a sweep air rate of 0.005m³/min.

The odour samples were analysed according to the Australian/New Zealand standard AS4323.3. The results for the 10 odour samples collected are summarised in Table 2.

Table 2 Odour Sampling Results – Gippsland Water Factory pilot plant (September 2007)

PARAMETER	ODOUR CONCENTRATION (OU)
Average	135
Minimum	50
Maximum	220

Analysis for sulphur gases was undertaken as per USEPA Method 15. The sulphur species tested for were:

- H₂S
- Carbonyl sulphide
- Methyl mercaptan
- Dimethyl sulphide (DMS)
- Carbonyl disulphide (CDS)
- Dimethyl disulphide (DMDS)

All sulphur species tested were below the limits of detection. This suggests that H₂S removal efficiencies were as high at the GWF pilot plant as the 85 – 100% removal of H₂S that was found in previous studies (Barbosa et al. 2004).

This is particularly impressive considering that the feed from the anaerobic reactors to the bioreactors contained dissolved sulphide levels of 180 mg/L – 240 mg/L at the time of testing. The mixed liquor suspended solids (MLSS) in the bioreactor ranged from 7025 mg/L – 7590 mg/L. The sludge age or solids retention time (SRT) in the bioreactor was 15 days.

The diffusers in the pilot plant are coarse bubble diffusers. The GWF full-scale plant will utilise fine bubble diffuser, which have proven to be much more effective than coarse bubble diffusers at removing odorous compounds (Barbosa et al., 2004). Therefore, the odour emissions from the full-scale plant should be equal to or less than those from the pilot plant.

The potential advantages of using activated sludge for odour removal are apparent, and include:

- Capital costs are lower than for other odour control technologies, provided air diffusion equipment already exists.
- The increased net capital and annual operation and maintenance costs are relatively low. These typically include higher-level corrosion specifications and some additional duct work.
- The technology appears to be relatively simple to operate.
- No chemicals are needed.

- Relatively little (if any) additional site space is required.
- High efficiency removal of odours.

BIOTRICKLING FILTERS

Process Description

Biotrickling filters (also known as bio-towers) are typically a fibreglass vessel, filled with an inert packing media on which a particular type of bacteria is grown. The bacteria include various thiobacillus species that are known for their ability to biologically oxidise reduced sulphur gases such as H₂S to H₂SO₄ and other compounds.

The odorous air is blown into the bottom of the vessel and up through the media on which the bacteria is growing. The odorous compounds in the air are dissolved into a bio-film with the bacteria and are oxidised into sulphates and other non-odorous compounds which are dissolved and disposed of as blowdown. The cleaned air is then exhausted from the top of the tower. As with most biological systems, biotrickling filters will adjust to changes in incoming air.

The media is irrigated to keep it moist, to control the pH to the desired level, and to provide nutrients to the bacteria. Either secondary effluent, or potable water to which nutrients are added, are used for irrigation of media.

Performance Data

A large bio-trickling filter system was installed at Western Treatment Plant (WTP) in Melbourne to treat odorous air from a sewer conveying raw sewage to the plant. Its design air flow is 126,000m³/hr and the EBRT is 16-18 seconds. The design specifications and the results of process proving for this system are shown in Table 4. Based on the results shown, this biotrickling filter demonstrated an odour removal efficiency of 98% (570 OU) and an H₂S removal of 99.6% (0.010ppm_v) (Bioway 2007).

Table 4 WTP Biotrickling Filter Design Specification and Results obtained during the Process Proving Trial (Bioway 2007)

PARAMETER	DESIGN SPECIFICATIONS	RESULTS PROCESS PROVING TRIAL
Inlet odour concentration; range	6,000 – 76,000 OU	18,000 – 60,000 OU
Outlet odour concentration; average and range	< 2000 OU*	570 OU 170-1900 OU
Inlet H ₂ S concentration; range and average	6 – 45.9 ppm _v	0 – 41.3 ppm _v
Outlet H ₂ S concentration; average and range	< 0.5 ppm _v **	0.010 ppm _v 0 – 0.080 ppm _v

* To apply within the statistical confidence limit of an olfactometric panel. As permitted in 95% of cases. Readings shall be measured in accordance with the procedures as specified in the Australian Standard.

** To apply to at least 99.5% of all H₂S readings, measured as the average of any ten consecutive readings taken at two minute intervals.

In the USA, performance data was collected from 20 bio-trickling filters treating air from process units at wastewater treatment plants. The average H₂S and odour removal rates were 94% and 72% respectively, with a large variation in the ability of the systems to remove total reduced sulphur organic compounds. The empty bed residence times (EBRT) in the bio-trickling filters tested ranged from 1.8 to 37 seconds, and inlet H₂S levels ranged from 0.1–1,350ppm. Both odour and H₂S removal efficiencies increased with increased contact times. For H₂S, a contact time of 10 seconds generally resulted in a removal efficiency of 90%, and at contact times of approximately 15 seconds, removal efficiencies of 98-99% were achieved. Overall odour removal rates ranged from 37–98%, and increasing contact time generally increased odour removal rates. (Easter et al. 2006)

As indicated above, the EBRT is the major parameter that impacts odour and H₂S removal in bio-trickling filters. The configuration of the bio-

trickling filter system also affects the removal efficiencies, with an apparent trend that some configurations are more efficient than others. However, as there are so many variables in each system, these are hard to quantify. Therefore, at GWF it was considered best to select a proven arrangement.

A bio-trickling filter system similar to that at WTP is installed at GWF following the pre-treatment of air in the bioreactors. There is confidence that the performance parameters can be met and that there will not be adverse odour impacts for the surrounding community upon discharge of treated air through the 25m stack.

Table 5 GWF Biotrickling Filter Design Specification

PARAMETER	DESIGN SPECIFICATIONS
Inlet odour concentration; range	500 – 5000 OU
Max. guaranteed outlet odour concentration	< 750 OU
Inlet H ₂ S concentration; range	6 – 45.9 ppm _v
Max. guaranteed outlet H ₂ S concentration	< 0.05 ppm _v

CHALLENGES

A number of challenges have been faced in the design and construction of the GWF odour control system. These have included cover design and installation, site ducting modifications, biotower installation and commissioning preparation.

Odour Covers

The main vessel that needed to be covered was the MBR 'doughnut' tank. This vessel is a 64m diameter round tank with a 32m diameter doughnut 'hole' in the middle where the MBR membrane units are housed in separate tanks. The bioreactor doughnut area of the vessel is required to be covered in order for the foul air to be collected and drawn off to the odour treatment facility. The shape and access

requirements for this structure are unique and the inclusion of the covers was an integral part of the tank design. The concrete walkways on and around the tank are specifically designed to allow the landing of odour covers as well as act as odour covers.

The odour cover for this structure incorporates epoxy coated precast concrete walkway panels, more than 200 individual fibreglass panels, as well as a number of aluminium flat panels. Due to the fast-tracked design-and-construct methodology used on this project and the long lead time on the delivery of the fibreglass panels, these aluminium panels are designed to incorporate the majority of aeration piping and instrumentation penetrations, and to take up any variance in the design.

Odour Ducting

The odour collection system includes more than 600m of fibreglass ducting, with diameters ranging from 80mm up to 1300mm. Similarly to the odour covers, the fibreglass ducting had a significant lead-time, and some of the drawings had to be issued to the fabricator prior to the completion of the final details of the design. In addition to this, the ducting has interface points with nearly every area of the facility. Since site measurements could not be taken to confirm these points prior to drawings being issued to the vendor for fabrication, this left a high probability that some interface connection points would not match up exactly. As a result, the construction team knew there was likely to be a requirement to make site modifications to the ducting that was delivered and therefore worked closely with the design team to ensure any modifications could be made as easily as possible. One of the key challenges with this was that despite widespread use of fibreglass in the industry, there was concern among the site workforce about the nature of the fibreglass work and the impact it may have on the health of those working nearby. To alleviate these concerns, the majority of cutting or wet joining of fibreglass was undertaken outside the usual hours of construction to minimise the number of people exposed. This meant the hours available in a given week for installation of odour ducting was less than had initially been planned and therefore a significant reworking of the delivery

program was undertaken to ensure this did not impact on the final project delivery date.

Biotowers

Each fibreglass shell for the biotowers is made up of four separate sections that slot into each other. To ensure these sections fit together as designed, each biotower shell is wound as one piece on a 3.6m diameter mandrel and then cut into the four sections required for the final product. The fibreglass shells for these vessels had been fabricated almost one year prior to their installation, which is a situation that had not previously occurred for the vendors. During this time, the shells had been stored in a yard and over time, they had warped slightly. The warping was minor and not detected until the vessels arrived on-site, but it was significant enough to prevent the sections fitting together with the ease that had been experienced during the previous installations. In order to overcome this issue, a leading edge was ground onto each of the sections and the gentle persuasion of some block and tackle sets eventually allowed for the installation of the vessels to be successfully completed.

Commissioning Preparation

The commissioning and operation of this odour collection system will be quite challenging due to the unique nature of its operating parameters. As can be seen in *figure 2*, there is a constant amount of foul air required to be drawn off the primary foul air sources. Under most operating conditions, all of this air is fed to the aeration blowers and into the MBRs. The blowers can then draw in fresh air to make up for any shortage. However, there are times when the air demand from the blowers is less than the volume of air required to be drawn off the primary foul air sources. During these times, the excess air volume is sent directly to the biotowers for treatment via a bypass duct. Since there is only one set of odour fans drawing air into the biotowers and this same air is being utilised by the aeration blowers, it is critical that the control logic around the operation of this system prevents the blowers and fans fighting each other for air. As such, controlling this will be complex and will require significant tuning in order to operate in an optimum fashion.

CONCLUSIONS

The design of the odour management solution for GWF uses innovative biological technologies to treat waste with extremely high odour potential. The design comprises of a three stage system using activated sludge bioreactors, multi-stage bio-trickling filters and a 25m high stack to ensure the local community is not affected by odour. The biological technologies used have been shown to effectively treat extremely high contaminant concentrations without the need for chemicals and with no off-site wastes. A pilot trial of the activated sludge bioreactors proved they effectively treated very high sulphide concentrations and emitted odour levels comparable to those from a conventional activated sludge plant. The performance of a bio-trickling filter system similar to that installed at GWF has been proven at WTP in Melbourne, and therefore the risk of GWF having an odour impact on the surrounding community will be minimal.

The design and construction of the GWF odour control systems met a number of challenges including cover design and installation, site ducting modification requirements, biotower installation and commissioning preparation.

As well as being an innovative solution that ensures the local community is not affected by odour, the odour management solution at GWF is more sustainable than odour control systems installed elsewhere, as pre-treatment is achieved through the activated sludge bioreactors, decreasing the size of the bio-trickling filter system required. The bio-trickling filter system removes odours from discharged air using biological processes, rather than relying on chemicals. The media in these biotowers has a much longer life than that associated with other odour control technologies and maintenance requirements are minimal.

Construction of GWF is expected to be completed early 2009, with commissioning to follow, and will make this sustainable odour management vision a reality.

ACKNOWLEDGEMENTS

The authors would like to thank the following persons and organisations for their input into the preparation and review of this paper:

- GWFA pilot plant team (incl. Tony O'Neill, Steve Kanara and Emily McDonnell)
- GWFA communications team (Leah Mether, Rose Thomas)
- Andrew Hodgkinson, Parsons Brinckerhoff

REFERENCES

- Barbosa, V. L., Burgess, J. E., Callan, J. L., Stuetz, R. M., (2004). *Optimisation of Activated Sludge Diffusion for Hydrogen Sulphide and Volatile Organic Compounds Removal*. WEF/A&WMA Odours and Air Emissions, 2004.
- Bioway, (2007). *Melbourne Water Odour Control Facility Manhole 1 Western Treatment Plant Process Proving Trial*.
- CH2M HILL (2007). *Odour Emissions Database Development - Best Practice Odour Emissions*.
- Daigger, G.T., Hodgkinson, A., Fries, K., (2007). *Using Membrane Bioreactors to Create Sustainable Water Reclamation and Reuse Systems*, www.ch2m.com
- Easter, C., Quigley, C., Witherspoon, J., (2006). *Biofilter and Biotowers for Treating Odors and Volatile Organic Compounds*. WEF/AWWA Odour and Air Emissions, 2006.
- EML Air, (2007), *Gippsland Water Factory: Pilot Wastewater Recycling Plant Emission Testing Report - September 2007*, EML Air Pty Ltd, Surrey Hills, Victoria, Australia.
- Trainor, S., McDonald, A., Olliff, M., Cesca, J., (2008). *From Vision to Reality, the Development of an Innovative and Sustainable Odour Management Solution at the Gippsland Water Factory*. Enviro08.

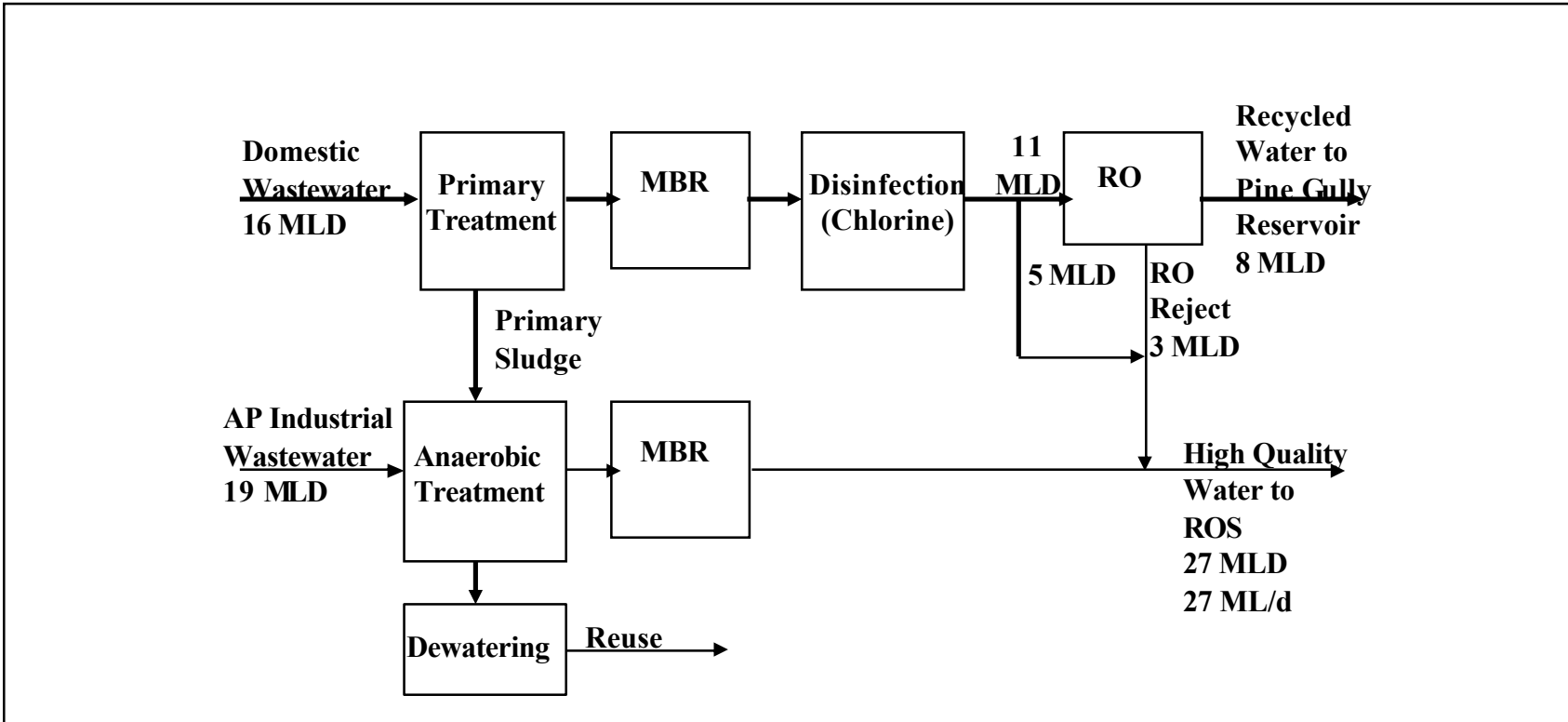


Figure 1 GWF process flow schematic

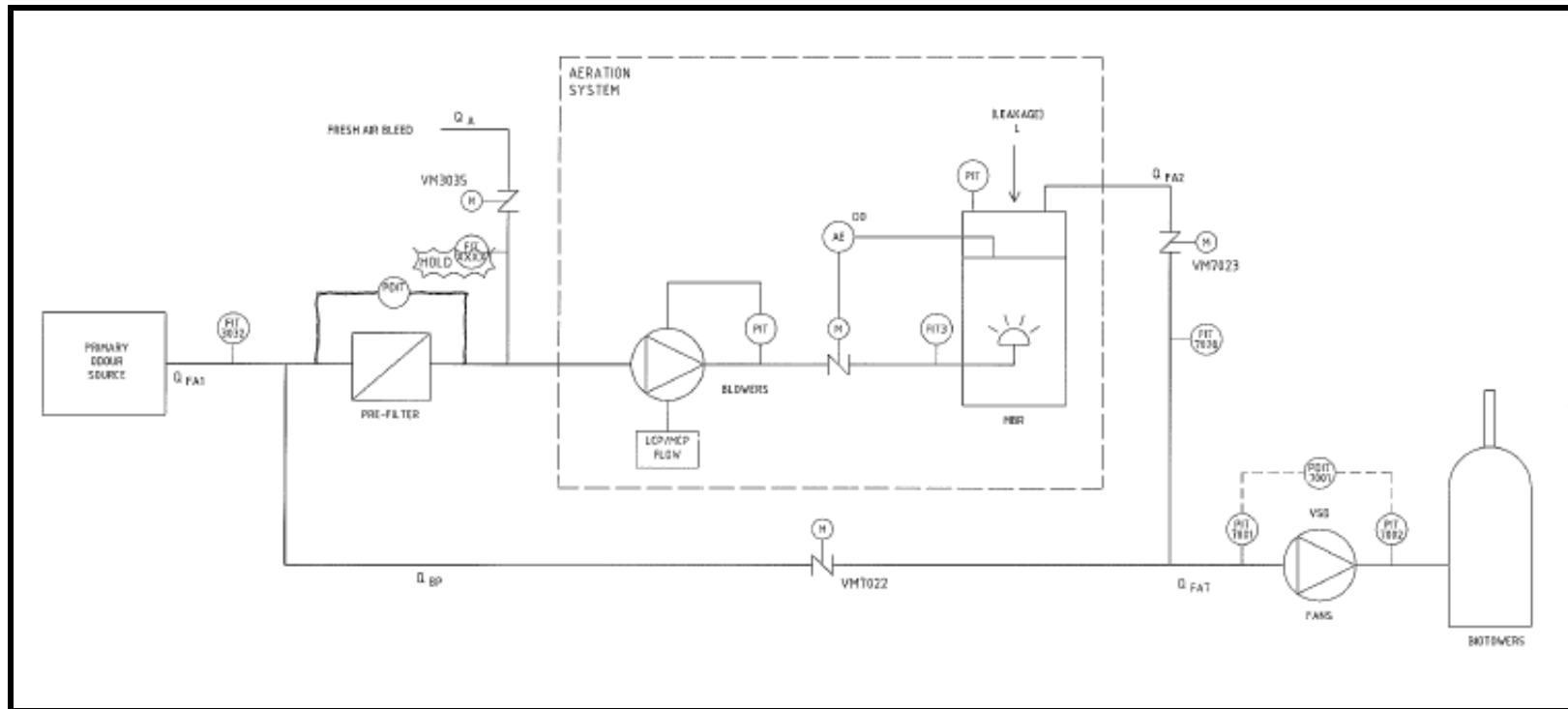


Figure 2 Process Flow Diagram of the GWF Odour Management Solution