Biofiltration systems for the treatment of waste gas from industrial plants

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ABSTRACT

Bord na Móna Environmental Ltd. has gained valuable experience over the years with the installation of over 500 biofilters, primarily in municipal and industrial wastewater treatment plants, food processing and more recently printing and coating applications. As a result, this paper will deal with the routes of successful biological air treatment and the pitfalls to avoid.

Since the mid 1990s Bord na Móna have concentrated their efforts on process development for VOC and industrial applications. New applications include treatment of airstream containing high concentration of H_2S, ammonia, VOC or indeed a combination of all three. The paper will cover new developments and new applications notably in solid waste composting plants, and in industrial applications. Success in biofiltration will be shown to be closely linked with in-depth analytical process engineering, accurate characterisation of waste gas streams, control of process conditions for optimisation of biological activity, and the physio-chemical properties of the filter media. Particular attention will be given to the successful application of biofilters for extremely high concentrations of sulphur compounds, up to 5000mg/$m^{3,}$ and the increasing use of biofilters for VOC elimination.

1 INTRODUCTION

In response to a rapidly changing world, with ever increasing pressures on our environment globally, we continue to develop and implement more stringent environmental legislation. Arising from this, and an increased understanding of the impact of pollutants, there is an increasing requirement for economic and environmentally sustainable treatment options for various types of emissions to the environment.

In the late 1980s Bord na Móna identified possible future use for peat as filtration media for treatment of waste air and water emissions. This led to the establishment of Bord na

Móna's Environmental business in 1991. The business has continued to grow at a pace, and is currently active in Ireland, the UK, USA, France, Spain and Italy.

This paper traces Bord na Móna's early experiences and developments with biofiltration systems for treating air emissions. These experiences, coupled with various innovations and ongoing developmental work over the years, have enabled Bord na Móna develop unique patented technologies. The Bord na Móna technologies can treat a range of applications from relatively straightforward odour emissions from municipal wastewater treatment plants through to difficult complex industrial emissions. Extensive application experience has been gained in treatment of off gases from municipal and industrial waste water treatment plants, various industrial emissions and from municipal solid waste handling and treatment facilities.

By adopting a bi-directional approach to process development, Bord na Móna has developed a successful biological treatment technology for the treatment of high levels of VOC (Volatile Organic Components). This technology has been applied by coating industries, paint booths, printing processes and various applications in the pharmaceutical sector. Bord na Móna Environmental Ltd. have been awarded patents on the original MÓNASHELL technology. More recently world wide patents have been granted for the enhanced filtration technology for VOC treatment.

2 MATERIALS AND METHODS

2.1 Biofiltration

Biofiltration by definition is the aerobic degradation of pollutants in the presence of a carrier media. The early development work on biofiltration technology concentrated on organic media, such as, peat, compost, wood bark etc. In general terms, organic compounds are degraded to carbon dioxide and water, while inorganic compounds, such as, sulphur compounds are oxidised to form oxygenated derivatives. The formation of these acidic compounds can lead to a lowering of pH of the filtration media; which in turn impacts on the performance of the system. Removal of the oxidised compound from the media is an important consideration in the design of biofiltration systems.

Biofiltration has long been considered to be something of a «Black Art» rather than a Science. Variations in system design, filtration media, process conditions, operational conditions and system controls all greatly impact on successful treatment. The track record for biofiltration system in the early 1990s was poor and these systems were not widely held to be reliable for air pollution application.

2.2 Research & Development programme

Bord na Móna identified the UK municipal market as a target market for biofiltration systems. A research and development programme was set up to establish the optimum operational conditions for the treatment of sulphur compounds (principally H_2S, Mercaptans and Alkyl Sulphides) using peat based biofiltration materials.

The outcome of these results can best be summarised as follows:

2.2.1 Peat/organic media based filtration systems are suitable for municipal applications and can treat levels typically up to a maximum of 50mg/m^3.

2.2.2 Two loading regimes were identified as optimum for airstreams with a maximum of 15mg/m^3 H_2S and 50mg/m^3 H_2S.

2.2.3 The limiting factor for treatment of sulphur compounds in the system was identified as pH. A control system based on the operation of an intermittent irrigation system was developed.

2.2.4 Various peat media were trialled and optimum media specifications identified.

2.2.5 Optimum operating parameters in terms of gas loading, temperature, pH and operation of irrigation system were identified.

In addition to the above, the importance of the physical and chemical properties of the media in assisting in capture and in providing the conditions for successful treatment were identified. One of the most important aspects of biofiltration technologies is the physico-chemical characteristics of the media.

The importance of having a homogenous matrix offering minimum resistance through which air will pass, making good contact with the surface of the media matrix cannot be over emphasised. The outcome of the R&D programme was that Bord na Móna could design and install systems offering process guarantees, conditional on the systems being operated within the correct parameters.

2.3 MÓNAFIL biofiltration technology

During this period Bord na Móna developed its patented MÓNAFIL granular peat media. This media is a fractionalised high density peat media. The media has a high «Air Filled Porosity» (85%) and exhibits excellent physical characteristics. It can be installed to a depth of 3 metres and has been shown to have a media life well in excess of five years. A further advantage is that the media can be regarded at the end of its life with up to 50% being available for re-use (2 years typical for compost –

wood bark). This technology is now also used extensively for treatment of off-gasses from municipal solid waste treatment facilities, including composting plants.

3 RESULTS AND DISCUSSION

Field experience on municipal applications confirmed the R&D findings that pH was indeed the limiting factor. If the system saw high levels of H_2S, it was found that the oxidative by-products of H_2S oxidation resulted in lowering in pH of the media. At low pH, while H_2S removal still remains high, odour removal efficiencies tend to deteriorate particularly if Alkyl Sulphides and Mercaptans are present in the air.

Many of the potential applications in the UK market were on coastal sites where saline infiltration was a feature resulting in difficult sludges with heavily concentrated air emission (levels up to 1000ppm H_2S). It was found that the peat media biofilters became overloaded with a drop in media pH and thus reduction in efficiency.

3.1 MÓNASHELL BIOFILTRATION TECHNOLOGY

Developments in biofiltration for treatment of high level sulphur contaminants enabled Bord na Móna compete in this sector. It was decided to develop a roughing filter for operation upstream of the Móna peat technology.

Shells were identified as a media offering the following potential advantages:

3.1.1 In-built buffering capability due to the chemical make-up of shells (calcium carbonate).

3.1.2 High air-filled porosity. (AFP)

3.1.3 Ability to sustain high irrigation rates and capacity to retain large quantities of water.

3.1.4 Shape and size of packing is in the correct range for good mass transfer.

3.1.5 Calcium Carbonates are known to be a good media for supporting biological activities.

Laboratory and field trials were carried out on shell-based systems. Early trial results indicated excellent results, so much so that it was decided to develop the process as a stand alone technology. Patents were applied for and the technology was launched in 1995. Since then, over 400 installations have been installed worldwide for airstreams with levels typically up to 500ppm H_2S.

To date systems have been installed on airstreams treating levels up to 2,000 ppm H_2S. Treatment for levels up to 10,000 ppm down to levels below 1ppm at the outlet have been achieved by operating multipass systems through a number of units in series.

3.2 Enhanced filtration technology for VOC treatment

As a result of market demands, and with a view to pending and current European VOC directives and legislation, a significant requirement was identified for low cost treatment of low to medium, and medium to high levels of air-borne VOC from industrial processes (chemical / pharmaceutical), paint booths, printers and industrial coatings.

Conventional wisdom held that biological treatment of medium to high level VOC air contamination was not possible due to poor solubility and the persistent nature of compounds. Conventional treatment was incineration, with the addition of supplementary fuel (high operation cost). The potential advantages that biological treatment offered were identified as low cost, low energy and environmentally sound and sustainable solutions.

From application experience, it was known that the main limiting factors when treating VOC are as follows:

- Limited solubility of many organic compounds leading to poor capture and treatment.
- Excessive biomass production leading to plugging of filter media with excessive back pressure and reduced airflow.

  In 1997 a VOC research project was initiated. From the outset it was decided to adopt a bi-directional approach to the development of a biological technology for treatment of VOC levels as follows:
- Explore the potential of Bord na Móna's existing technologies for use on VOC application.
- Enhancement of existing process by combining existing Bord na Móna processes with other technologies to enhance treatment and effect the following:
  - Increase mass transfer of contaminants to the aqueous phase
  - Treat high concentration regimes
  - Control excess biomass over growth.

At the outset it was demonstrated that MÓNASHELL was capable of removing 15-20g of carbon per hour. This value is consistent with other biological systems.

Two dynamics were explored to enhance solubility and capture as follows:

3.2.1 Recirculation of air

A dynamic had been developed on a high H_2S application whereby treated air was recirculated to the inlet of the filter. This has a number of effects as follows:

3.2.1.1 Dilution of inlet concentration

3.2.1.2 Increased rate of mass transfer (gases to Aqueous) overcoming problem of insolubility.

3.2.1.3 Improvement of elimination capacity

This dynamic effectively allows the increase of the elimination capacity of the filtration system from circa 20g/m^3filter/hr to circa 60g/m^3filter/hr for the same net contact time. Thus, high removal efficiencies are also achievable.

3.2.2 Electromagnetic stimulation

As part of a study to enhance solubility the use of electro-magnetic stimulation of the water was also examined. While carrying out this work it was noticed that use of electromagnetic stimulation enhanced system performance and prevented excess biomass formation.

Supplementary nutrients are not added in the process. The system effects metabolism of solvents with only minimal synthesis of biomass.

Conventional biological systems operate on the basis of converting pollutants to biomass. The dynamic in Bord na Móna's enhanced technology is reliant on metabolic activity to produce CO_2, H_2O and exothermic energy.

The first commercial installation on high level VOCs was commissioned at B.P.I. Ardeer, a printing application in Scotland in February 2002. This system is monitored remotely and has been operating successfully achieving specified outlet levels. The second phase of the project is currently under construction.

4 CONCLUSIONS

The experience which Bord na Móna has gained over the years has proved that biological technologies can be successfully applied to difficult applications with remarkably predictable performance.

Biological systems need to be engineered such that all critical parameters can be monitored and controlled. Biofiltration is successfully emerging from the shadows as a reliable, low cost option for a broad range of air treatment applications. It is now becoming apparent that biological treatment will play a far more significant role in achieving environmental control on air emissions.

Further related areas of study under review at present are:

- Comparison of different shell based media.
- Development of Multi-Pass system versus recirculation (reduced power requirements).
- Buffering of emission from non continuous processes.
- Optimum maintenance requirements for control of pressure drop through system.
- Co flow versus counter flow.

Case Studies

Table 1.
MÓNASHELL case study

Location	**Sewage Treatment Plant, Ireland**
Application	Treatment of emissions from picket fence thickener
Date of installation	April 1998
Biofilter size	3 m^3
Total gas flow rate	160 m^3/hr
Inlet odour concentration	12,722 ou/m^3
Outlet odour concentration	294 ou/m^3
Odour removal efficiency	98%*

* Determined by Force Choice Dynamic Olfactometer

Table 2.
MÓNASHELL case study

Location	**Sewage Treatment Plant, Ireland**	
Application	Treatment of emissions from biotower	
Date of installation	September 1997	
Biofilter size	70 m^3	
Total gas flow rate	1,000 m^3/hr	
Removal efficiency for individual compounds	Inlet Concentration	Removal
H_2S	40-100	98-100%
Mercaptans	37 ou/m^3	88%
Dimethyl Sulphide	97%*	95%

* Determined by Force Choice Dynamic Olfactometer

Table 3.
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Table 5.
MÓNAFIL case study

Location	**Animal by-product Rendering**
Application	Factory ventilation air, non-condensable process gases
Pre-treatment of non-condensable gases	Cyclones for removal of particulates packed tower acid scrubber
Biofilter volume	250 m^3
Total gas flow rate	25,000 m^3/hr
Inlet odour concentration (after pre-treatment)	10,000 – 50,000 ou/m^3
Performance	Mean odour removal efficiency across filter bed
Date	
December 1992	98.7%
May 1993	98.5%
April 1993	99.5%

* Determined by Force Choice Dynamic Olfactometer

Table 6.
MÓNASHELL case study

Location	**Industrial Plant, Ireland**
Application	Treatment of emissions from anaerobic digestor
Date of installation	January 1998
Biofilter size	24 m^3
Total gas flow rate	200 m^3/hr
Inlet odour concentration	434,531 ou/m^3
Outlet odour concentration	508 ou/m^3
Odour removal efficiency	99%*
Inlet H_2S concentration	1,600 ppm

* Determined by Force Choice Dynamic Olfactometer

Table 7.
MÓNAFIL case study

Location	**Pharmaceutical Plant, Ireland**
Application	Treatment of emissions from industrial treatment plant
Date of installation	September 1997
Biofilter size	70 m^3
Total gas flow rate	3,500 m^3/hr

Table 7.1
VOC analysis by GG-MS+

PARAMETER (mg/m^3)	BIOFILTER INLET	BIOFILTEROUTLET	% REMOVAL
Toluene	8.50	1.00	88.20
Dichloromethane	106.60	27.50	74.20
MIBK*	3.00	0.07	97.90
TOH**	1.80	0.90	50.00
Total Hydrocarbon	119.90	29.50	76.40

* MIBK = Methyl is obatyl Ketone

** Total Other Hydrocarbons

Table 8.
MÓNAFIL case study

Location	**Composting plant, Italy**
Application	Treatment of emissions from composting facility
Date of installation	1996
Biofilter size	300 m^3
Total gas flow rate	20,000 m^3/hr

Table 8.1
VOC analysis by GC-MS+

PARAMETER (mg/m^3)	BIOFILTER INLET	BIOFILTEROUTLET	% REMOVAL
Toluene	3.6	0.7	80.5
Limonene	28.9	9.6	66.8
Other $C_{10}H_{16}$	1.8	0.3	83.3
TOH*	9.9	2.3	76.8
Xylenes/Benzenes	5.9	2.3	61.0
Total Hydrocarbon	50.1	15.2	70.0

* Total Other Hydrocarbons

Table 8.2.
Removal of odorous compounds from air streams utilising MÓNASHELL

COMPOUND	CONCENTRATION ppm	% REMOVAL
Mercaptan	20	100
Mercaptan	70	97
Ammonia	30	100
Ammonia	45	100
Ammonia	100	100
Triethyl Amine	15	100
Triethyl Amine	35	96

Table 9.
MÓNASHELL enhanced biofiltration case study

Location	**Printing Plant, Scotland**
Application	Treatment of emissions from 8-colour printer
Date of installation	2001
Biofilter size	2 x 46 m^3
Total gas flow rate	11,500 m^3/hr
Typical Emissions	500-1200 mgC/m^3
Components	Isopropyl Alohol, MEK, Ethyl Acetate, Butyl Acetate, Ethanol
Removal Efficiencies	to <150 mg C/m^3