CrumRubber™ Data Sheet

Product Overview

"Anua Clean Air International offer proven, patented clean air bio-technologies, which provide best-in-class process performance with the lowest utility and life cycle costs"

As part of an extensive research program in the early 2000's to develop a catalytic roughing filter for H2S removal Bord na Mona identified Crumb Rubber as an ideal media with the capability to catalytically remove and convert H2S to sulphate. The Sulphate deposited on the surface of the crumb rubber media (origin of material waste automobile tyres). The media could be regenerated by continuous or intermittent flushing with water. Typical removal efficiencies for levels from 10 to 200 ppm of H_2S ranged from 30 to 70 percent. Initial attempts to get the media to operate as a support media for biological treatment were not successful and this was attributed to the hydrophobic nature of the media. The concept was patented as a roughing process for reduction of H2S prior to biological filters. This allowed for reduced contact times and improved performance with the biological filter.

Figure 1 - CrumRubber Pilot Plant

In 2009 a new research program was commenced to identify an inert recovered Biotrickling media for treatment of H_2S. The testing of Crumb Rubber on a high strength H_2S air stream was resumed on a high strength airstream containing continuously high levels of H_2S (between 200ppm and 400ppm). The initial work in the early 2000's demonstrated the crumb rubber media had an excellent affinity for capture of H_2S and conversion to sulphate. However early attempts to establish a biofilm on the surface of the media were not successful. Pilot work recommenced in 2009 and ran for three years on an airstream extracted from a transfer point on an industrial waste water anaerobic digester. The initial focus was on establish conditions under which an attached growth biofilm could form on the surface of the media. Over a three-year period, critical parameters were optimised and a means of developing successful biological treatment were perfected with this important media. Treatment efficiencies in excess of 98% was achieved on levels up to and in excess of 400ppm. Following successful process development and optimisation the plant was operated for an 18-month period. The airstream that was being piloted had lower oxygen levels and higher carbon dioxide levels that ambient air. This was due to the anaerobic digestion process. Based on the excellent performance of the system and the likely hood that CrumRubber had an affinity for volatile siloxanes the next logical step was to adopt the process for biogas and landfill gas treatment.

In 2012 Bord na Mona had installed gas engines on its own landfill and issues quickly arose due to excessively high levels of H_2S and volatile siloxanes, arising from this trial was set up in 2013/2014 on what would be classified as a very difficult landfill gas application and operated for circa 12 months. The landfill in question took in a high percentage of builder's waste so H2S levels were exceptionally high. Kildare. A three stage 1 m^3 pilot plant was designed and build and successful trials were carried out on the Landfill gas using a variation of the CrumRubber Biotrickling technology. Landfill gas H_2S Levels in excess of 2000 ppm were successful treated with this technology. The data from the trial was used to scale up the technology to treat all the landfill gas prior to combustion in the gas engines. These units were manufactured and installed in 2015 and commissioned in Autumn 2015. The units have been in operation for over 12 months successfully removing H_2S. What has been noticeable since the start up is that in addition to the removal of H_2S the units have also been successful in removing the larger volatile siloxane compounds. This combination has increased engine availability, increased oil change and decoking intervals on the engine and reduced reliance and costs associated with frequent activated carbon change outs.

Figure 2 - CrumRubber Biogas Plant installed as part of a 5MW Landfill Gas Utilisation Plant at Drehid Landfill, Ireland

The application was characterised by the exceptionally high levels of H_2S given the technologies ability to cope with such high H_2S levels, the affinity CrumRubber has for Volatile Siloxanes, and the low operating cost when compared to more conventional technologies, it is clear that CrumRubber will have a big future in enabling energy recovery in the form of clean biogas and landfill gas in the resource recovery sector.

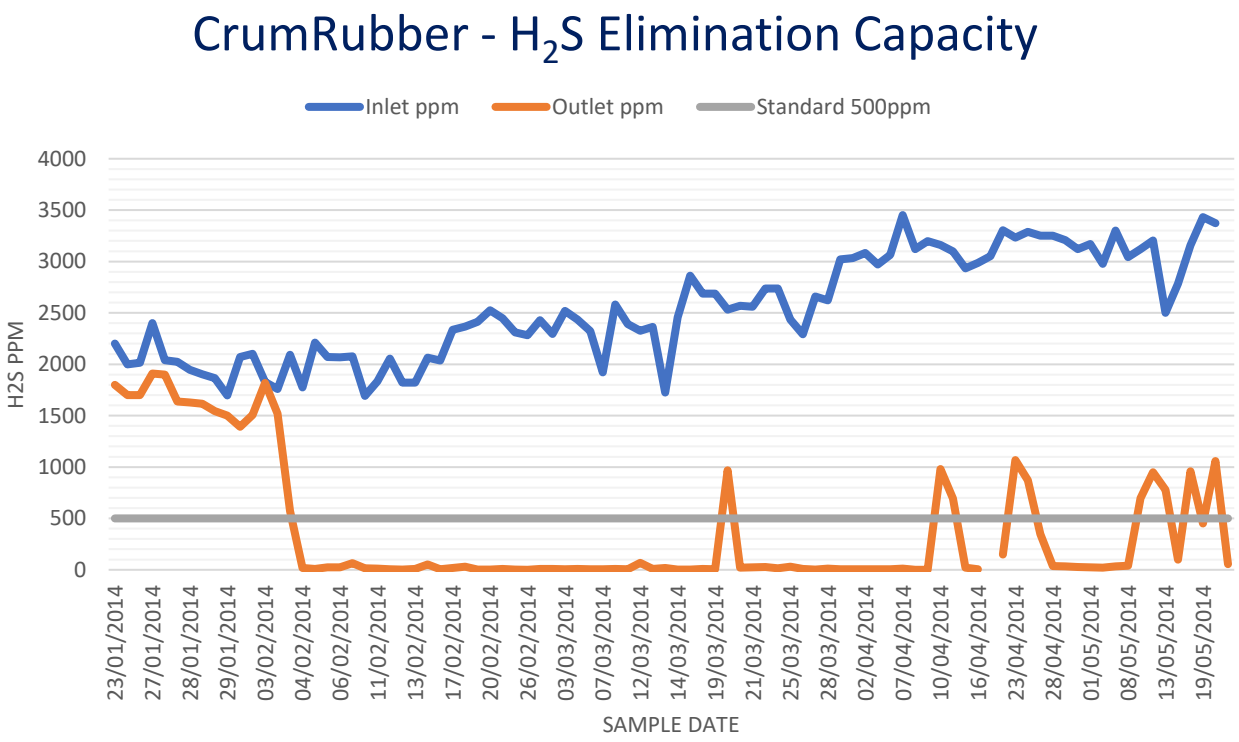

Figure 3 - CrumRubber H_2S Elimination Capacity

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Treatment Details and Product Selection Considerations

CrumRubber™ Air Treatment and Product Selection Considerations		
Compound	**Concentration Range**	**Removal Efficiency**
Odour	1000 - 10,000,000 OU_E	90% +
H_2S	0 - 500 ppm (1000 ppm max)	95% +
VOC's	0 - 100 mgC/m^3	50%
Reduced Sulphur Compounds	0 - 50 ppm	98% +
Amines	0 - 10 ppm	98% +
Ammonia	0 - 20 ppm	95%

Typical design contact times.	25 to 55 seconds
Water Consumption per kg H_2S.	3 m3
Typical Media Life.	15 years +
Typical Pressure Drop per m^3.	100 pa
Comments on Selection of Technology	This technology was developed as a inert biotrickling filter for high H2S applicatons, particularly suited where water availability a high cost as media can with stand low pH
Comments on Life Cycle Cost	Inert media biotrickling filter with low running cost due to inert nature of media. Polishing required if high odour removal efficiencies are required

Figure 4 – CrumRubber Air Treatment Applications

CrumRubber™ Biogas Treatment and Product Selection Considerations		
Compound	**Concentration Range**	**Removal Efficiency**
Odour	N/A	N/A
H_2S	0 - 2000 ppm (4000 ppm max)	85 - 95%
VOC's	N/A	N/A
Reduced Sulphur Compounds	N/A	N/A
Amines	N/A	N/A
Ammonia	N/A	N/A

Typical design contact times.	50 to 100 + seconds
Water Consumption per kg H_2S.	0.2 m3
Typical Media Life.	10 years +
Typical Pressure Drop per m^3.	75 pa
Comments on Selection of Technology	Inert media for H2S removal, also go0d removal for long chain volatile organic siloxanes
Comments on Life Cycle Cost	Ideal technology to complement activated carbon polishing and significantly reduce cost of landfill and biogas cleaning.

Figure 5 – CrumRubber Biogas Applications

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Application	Odour		H_2S		VOC's		Reduced Sulphur		Amines		Ammonia	
ACAI Technology	Odour [Inlet Concentrations] [Ou_E]	Removal Efficiency [% $_{OuE}$]	H_2S [Inlet Concentrations] [ppm]	Removal Efficiency [% $_{H2S}$]	VOC's [Inlet Concentrations] [mgC/m^3]	Removal Efficiency [% $_{g.C/m3}$]	DMS [Inlet Concentrations] [ppm]	Removal Efficiency [% $_{H2S}$]	Amines [Inlet Concentrations] [ppm]	Removal Efficiency [% $_{ppm}$]	Ammonia [Inlet Concentrations] [ppm]	Removal Efficiency [% $_{ppm}$]
Mónafil	1000 - 50,000	95% +	0 - 30ppm (50 ppm max)	98% +	0 - 100	50%	0 -10	90%	0 - 10	99% +	0 - 20	98%
Mónashell [Single Stage]	1000 - 100,000	98% +	0 - 50 ppm (100 ppm max)	98% +	0 - 200	50 - 80%	0 - 30	95%	0 - 5	95% +	0 - 30	95%
Monashell EBF	1000 - 40,000,000	99.9% +	0 - 2000 ppm (4000 ppm max)	99.9% +	0 - 1000	90 - 95%	0 - 500	99%	0 - 50	98% +	0 - 100	98%
Monashell Dual Pass	1000 - 4,000,000	99% +	0 - 200 ppm (500 ppm max)	99.5%+	0 - 400	85 - 95%	0 - 100	98%	0 -20	98% +	0 - 50	98%
Monashell Dual Pass/Dual Media	1000 - 4,000,000	99% +	0 - 200ppm (1000 ppm max)	99.5%+	0 - 400	85 - 95%	0 - 100	98%	0 -20	98% +	0 - 50	98%
CrumRubber	1000 - 10,000,000	90% +	0 - 500 ppm (1000 ppm max)	95% +	0 - 100	50%	0 - 50	85%	0 -10	98% +	0 - 20	95%
Hybrid Multi-Media Multi-Stage [Crumb Rubber/Shell Media]	1000 - 20,000,000	99.9% +	0 - 1000 ppm (2000 ppm max)	99.9%+	N/A	50 - 80%	0 - 100	98%	0 -20	98% +	0 - 50	98%
CrumRubber [Biogas/Landfill Gas]	N/A	N/A	0 - 2000 ppm (4000 ppm max)	85-95%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lava	1000 - 50,000	95%	0 - 30ppm (100ppm max)	98%+	0 - 50	20 - 50%	0 - 10	90%	0 - 5	90%	0 - 20	80%
Woodchip	1000 - 20,000	85%	0 - 10ppm (30ppm max)	90%+	0 - 100	50%	0 - 5	80%	0 -5	90%	0 - 30	90%

Table 1 - Anua Clean Air Product/Treatment Matrix

CrumRubber – Air Treatment

The original CrumRubber technology was developed as a catalytic pre-filter with a washing cycle for removal of sulphates from the surface of the media. In its current iteration, the use of the media as an attached growth Biotrickling process has been perfected. The system is configured with continuous recirculation to reduce water consumption and as the media is very resilient it can be operated at very low pH (<2) with our any break down of the media. The system is ideal of low to medium flow rates with high levels of H_2S.

Typical Applications:

- Tanker Discharge Points.
- Transfer points on Aerobic digesters.
- Sludge Centrifuges.
- Sludge process and storage tanks.

CrumRubber/Monashell – Air Treatment [Multi-media/Multi-stage]

By combining an Inert first stage of treatment which can be operated at low pH targeted at removing high levels of H_2S with a second Monashell Biotrickling stage which is operated at neutral pH (required for VOC and organic sulphur groups), we can combine the best of both technologies to effect very high removal efficiencies and elimination capacities on difficult airstreams with very low running costs due to low water consumption and the extended media life on the Monashell due to removal of most of the H_2S in the first stage. This combination in terms of performance and costs per kg of sulphur removed offers exceptional low operating costs.

Typical Applications:

- Tanker Discharge Points.
- Transfer points on Aerobic digesters.
- Sludge Centrifuges.
- Sludge process and storage tanks.

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CrumRubber – Landfill Gas/ Biogas Cleaning

Having successfully deployed the technology on transfer points from Anaerobic digesters with low oxygen and high carbon dioxide levels, a study was undertaken in 2004 to develop the technology for Landfill gas and Biogas applications. Trials were run over a twelve-month period and the technology was scaled up in 2015. The system is operated using multiple stages as a Biotrickling process. The H_2S is converted to Sulphate and elemental sulphur and this is released from the system in the purge water. Excellent removal was achieved on H_2S and removal of high molecular weight volatile siloxanes was also achieved. The system is ideal for use in combination with activated carbon as a polishing filter and greatly reduces the running cost and increases availability of Landfill gas/ Biogas Engines.

Figure 6 - CrumRubber Biogas Cleaning Plant

Typical Applications:

- Biogas cleaning
- Landfill gas cleaning
- Biomethane production
- Syn gas cleaning
- Mine gas cleaning

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Application ACAI Technology	Typical design contact times.	Water Consumption per kg H_2S.	Typical Media Life.	Typical Pressure Drop per m^3.	Comments on Selection of Technology	Comments on Life Cycle Cost
Mónafil	36 to 55 seconds	46 m^3	7 years ++	100	In general ideal for high volume airstreams with low levels of VOC, reduced sulphur, amines and ammonia.	Long media life and low pressure drop gives excellent life cycle cost on high air volume applicatons such as composting
Mónashell [Single Stage]	25 to 55 seconds	0.4 m^3	5 years	50 pa	In general for ideal airstreams with moderate levels of H2S, VOC, reduced sulphur, and ammonia.	Low water consumption, low pressure drop and no requirement for carbon polishing gives very low life cycle cost
Monashell EBF	36 to 90 seconds	0.4 m^3	2 - 5 years	250 pa	This technology was developed for high high levels of H2S and VOC's generally used for industrial process emissions	Low life cycle costs for high high VOC and H2S emissions when benchmarked against chemical scrubbers and Thermal oxidisers
Monashell Dual Pass	18 to 36 seconds	0.4 m^3	5 years	100 pa	In general ideal for high strength airstreams where two stages of treatment required (no requirement for carbon polishing.	Dual pass negates the requirement for Carbon polishing so low running cost due to this and low water and power consumption for Monashell
Monashell Dual Pass/Dual Media	18 to 36 seconds	0.4 m^3	8 years	75 pa	Ideal for high strength H2S airstreams where two stages of treatment and a long media life is required (no requirement for carbon polishing)	Similar performance to dual pass but media life enhanced by use of denser shells in first stage so lower running cost due to less frequent media replacement
CrumRubber	25 to 55 seconds	3 m^3	15 years +	100 pa	This technology was developed as a inert biotrickling filter for high H2S applicatons, particularily suited where water availability a high cost as media can with stand low pH	Inert media biotrickling filter with low running cost due to inert nature of media. Polishing required if high odour removal efficiencies are required
Hybrid Multi-Media Multi-Stage [Crumb Rubber/Shell Media]	25 to 55 seconds	2.4 m^3	10 years +	120 pa	This dual stage system offers the High H2S removal and long media life of CrumRubber coupled with excellent organic sulphur, VOC and odour removal of Monashell. Monashell media enhanced by factor of up to 5.	Hybrid with CrumRubber stage followed by Monashell this is ideal for very high H2S applications where very high odour removal and long media life is a requirement.
CrumRubber Biogas/Landfill Gas	50 to 100 + seconds	0.2 m^3	10 years +	75 pa	Inert media for H2S removal, also go0d removal for long chain volatile organic siloxanes	Ideal technology to complement activated carbon polishing and significantly reduce cost of landfill and biogas cleaning.
Lava	36 to 55 seconds	46 m^3	15 years +	100 pa	In general media is suitable when used with a carbon polishing filter for removal of low to moderate levels of H2S. Application limited by water availability and if no final effluent available running costs due to consumption of water, carbon and power is high	Lava is suitable for low to moderate H2S levels where high volumes of water are available to maintain pH very often carbon is used as a polisher which can leave life cycle costs high
Woodchip	50 to 90 seconds	46 m^3	2 years	250 pa	Wood chip media is low cost but requires long contact time, high water to work effectively and frequent change out.	Wood chip is a low performing media which requires very long contact times and has limited application. In general low media life and high pressure negate lower capital investment.

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