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Performance of Field Based Activated Carbon Systems for Odour Control

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Community tolerance for odours from sewer infrastructure is lessening, providing pressure to wastewater utilities to target and treat odour emissions from sewer networks. Gas phase odour abatement systems within sewer networks typically target hydrogen sulfide (H_2S) as an odorant and overall odour indicator. However other compounds can occur naturally, or be present from trade waste, that are either odorous themselves or may impact on the performance of odorant removal in odour abatement systems. Activated carbon (AC) systems adsorb most contaminants during their lifetime until most active sites are depleted. Samples from the inlet and outlet of 6 AC filters in Sydney and Melbourne (Australia) were taken monthly over 18 months and analysed for volatile sulfurous compounds (VSCs) using gas chromatography (GC) coupled with a sulfur chemiluminescence detection (SCD). H_2S was measured by Jerome 631-X hydrogen sulfide analyser for each sample. Each sample returned approximately 14 VSCs. After screening the data for wet weather and cooler periods, 6 VSCs were studied further. This paper evaluates and compares the performance of 6 activated carbon filters for each compound identified and each appropriate grouping of compounds. H_2S and methyl mercaptan were found to be removed well, yet dimethyl disulfide was found to have a negative removal more often than it had a positive removal. Dimethyl sulfide and dimethyl trisulfide also suffered from negative removals, yet not as often as dimethyl disulfide. Carbon disulfide was removed as often as it was released.

1. Introduction

Community complaints for odours from sewer infrastructure is increasing, placing pressure on wastewater utilities to target and treat odour emissions from sewer networks (Mudliar et al., 2010). Gas phase odour abatement systems within sewer networks typically target hydrogen sulfide (H_2S) as the key odorant and overall odour indicator (Perez et al., 2010). However, other compounds can occur naturally, or be present from trade waste that are either odorous themselves or may impact on the performance of odorant removal in odour abatement systems (Sivret et al., 2013, Wang et al., 2014).

Sivret and Stuetz (2010) surveyed nine Australian water utilities to identify the use of different odour treatment gas phase technologies. They found that of the 204 odour abatement units the utilities identified, 76% of these were adsorption based systems with approximately half being activated carbon (AC) systems. Whilst other operational performance formulas of odour abatement systems exist, such as elimination capacity, removal efficiency is most commonly reported as per the formula below (Deshusses et al., 2001):

$$Removal\ Efficiency\ (RE) = \frac{C_{in}-C_{out}}{C_{in}} \times 100\ (\%) \qquad (1)$$

Samples are taken on the inlet and outlet in order to determine the above parameters. In general, H_2S is sampled more frequently than other contaminants as a common surrogate for all odours and typically used to identify the adsorption capacity of isolated contaminants for AC systems. This is primarily due to its prevalence in wastewater systems, but also due to the ease in which it can be measured and logged. Other compounds often require more thorough sampling and analysis to obtain inlet and outlet information that can be time consuming and expensive (Wang et al., 2012, Wang et al., 2014). Where multiple contaminants are evaluated for AC systems, these are typically only for a small number of sample points, typically only on

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startup to establish performance. This makes it difficult to evaluate the performance of AC systems throughout their useful life. The combined effect of multiple contaminants is poorly understood, particularly where the presence of one substance may cause another to desorb. The goal of this study was to identify expected removal efficiencies for different VSCs in activated carbon systems operating in the field.

2. Methodology

Samples from 9 AC based odour control systems at sewer pumping in two of Australia's major cities, Sydney and Melbourne, were collected over 18 months. Sample locations were from both the inlet and outlet of the units, allowing removal rates to be determined.

Samples were analysed for volatile sulfur compounds (VSCs) using gas chromatography (GC) coupled with a sulfur chemiluminescence detection (SCD). Hydrogen sulfide was measured using a Jerome 631-X hydrogen sulfide analyser (Arizona Instruments, USA) (Wang et al., 2015, Sivret et al. 2014). Each sample returned approximately 6 VSCs. A list of compounds identified, their odour descriptor, odour threshold and common sources are presented in Table 1.

Table 1: Volatile sulfur compounds found in sewers (adapted from Suffet et al. (2004))

Odorant	Abbreviation	Descriptor	OTV (ppmv)[A]	Common Sources
Carbon disulfide	CS_2	Disagreeable, sweet	0.21	2
Dimethyl sulfide	DMS	Decayed cabbage	0.000033	3, 4, 5
Dimethyl disulfide	DMDS	Rotten cabbage	0.0022	3, 4, 6, 7, 8
Dimethyl trisulfide	DM3S	Sickening, putrid, foul, decaying, garlic, onion	Unknown	3, 5
Hydrogen sulfide	H_2S	Rotten eggs	0.00041	1
Methyl mercaptan	MM	Unknown	0.00007	3

A - OTV: Odour Threshold Value, Nagata (2003)
1 – Anaerobic respiration of sewage
2 – Solvent
3 – Bodily functions
4 – Bacteriological action
5 – Decomposition of plants and animals
6 – Polymer and/or petroleum manufacturing
7 – Pesticides
8 – Food and soil additives

The magnitude of this field based dataset (in terms of volume of samples and the range of compounds identified for such a duration) allowed it to be filtered for known outside influences on activated carbon performance in order to produce a baseline of 'normal' operating conditions, whilst still maintaining sufficient data to provide meaningful results. The factors that were filtered out are listed below:

- Wet weather – samples with cumulative rainfall for the previous 7 days greater than 50mm
- Spikes – samples where inlet concentration of any contaminant greater than 3 times the standard deviation above the average
- Non-'warm' period – average of maximum daily temperatures for each city were used. Data was averaged over the preceding 30 days. The 'warm' period was defined as the duration from where the 30 day preceding average increased above the 60th percentile temperature until when it decreased below the 60th percentile temperature. Figures 1 and 2 show these times for Sydney and Melbourne during the sampling times.

The remaining data was evaluated for completeness. Sites where there was insufficient data to make a meaningful analysis (generally <5 data points) were removed. Six sites were deemed to have sufficient information to analyse further. Details of these sites are shown in Table 2. Each carbon was replaced close to the start of the sampling period.

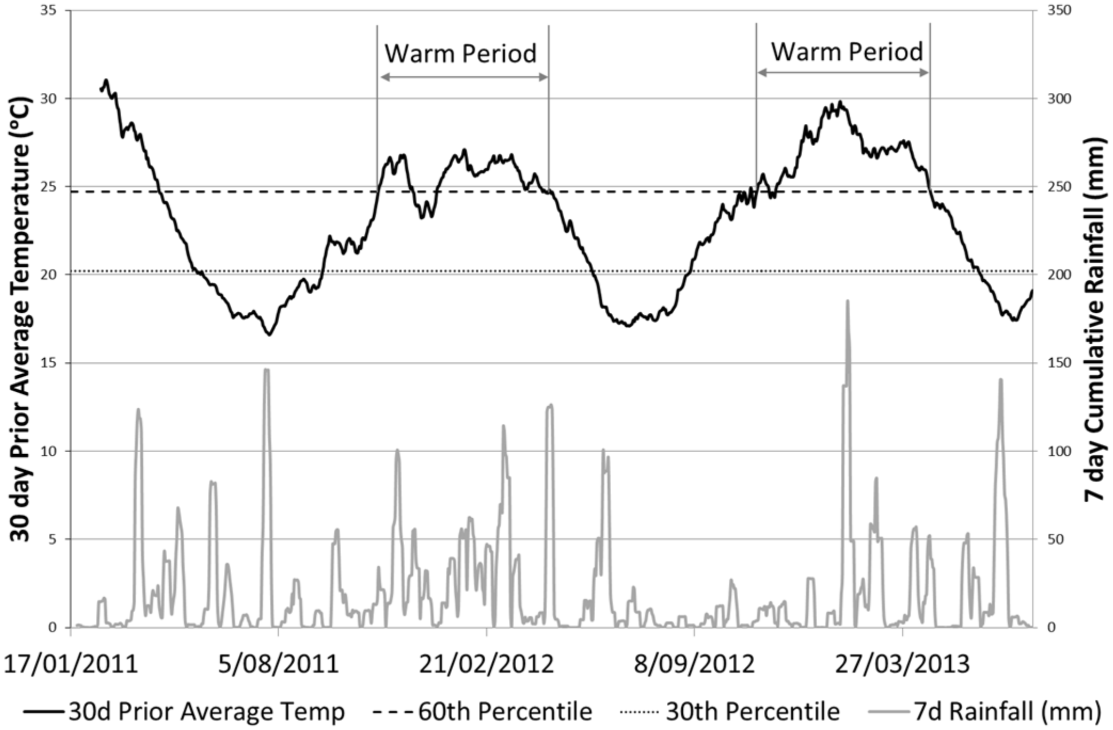

Figure 1: Sydney meteorological data over sampling period

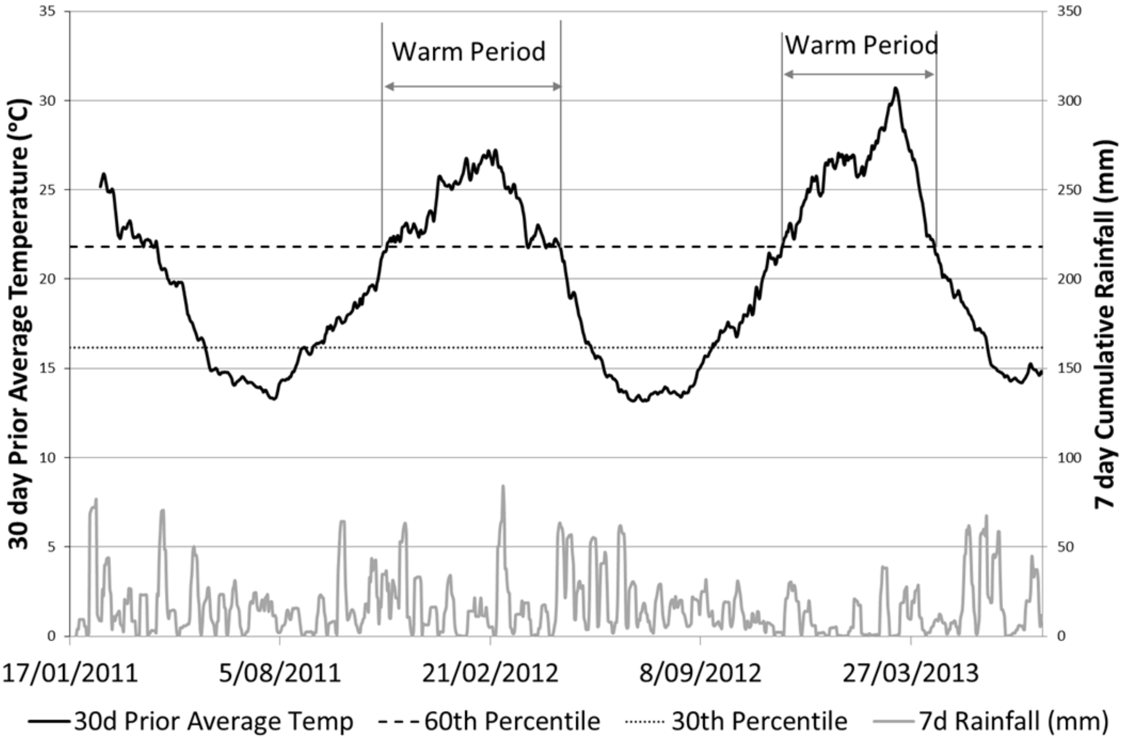

Figure 2: Melbourne meteorological data over sampling period

Table 2: Site details

Site	Year installed	City	Carbon type	Upstream chemical dosing	Approximate contact time	Design flow rate
AC-3	2003	Sydney	Potassium Iodide (KI) Impregnated	Ferrous chloride	3.0 s	4.0 m^3/s
AC-5	2010	Sydney	Caustic impregnated	Ferrous chloride	3.0 s	4.0 m^3/s
AC-6	2003	Sydney	Potassium Iodide (KI) Impregnated	Ferrous chloride	3.5 s	3.0 m^3/s
AC-7	2003	Sydney	Potassium Iodide (KI) Impregnated	Ferrous chloride	4.4 s	3.0 m^3/s
AC-8	2009	Melbourne	75% activated alumina / 25% proprietary 'high H_2S' activated carbon	None	5.4 s	0.15 m^3/s
AC-9	2006	Melbourne	Caustic impregnated / virgin carbon blend [Note 1]	None	Unknown	0.39 m^3/s

Note 1 – Blend proportion and volume unknown

3. Results

3.1 Inlet concentration

The inlet concentration for each VSC is provided in Table 3. AC-8 generally experienced lower concentration of VSCs than other sites. AC-3 and AC-5 generally experienced a greater concentration of VSCs than other sites.

Table 3: Inlet concentration

	Carbon Disulfide	Dimethyl Sulfide	Dimethyl Disulfide	Dimethyl Trisulfide	Hydrogen Sulfide	Methyl Mercaptan
	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	(mg/m^3)	($\mu g/m^3$)
AC-3	15.8 (10.7 to 190.2)	136.4 (38.1 to 331.2)	10.9 (3.7 to 41.5)	13.2 (3.8 to 22.3)	3.83 (2.58 to 10.18)	873.7 (157.6 to 1464.8)
AC-5	16.8 (14.9 to 23.8)	89.3 (61 to 124.2)	6.2 (2.7 to 68.4)	7.7 (2.9 to 71.7)	4.81 (1.16 to 19.52)	400.2 (66.3 to 1335.8)
AC-6	10.4 (nd to 47.7)	90.6 (11.4 to 100.2)	9.9 (1.7 to 15.2)	7.4 (1.2 to 10.4)	2.02 (0.54 to 3.00)	423.1 (39.9 to 741)
AC-7	10.0 (5.5 to 11.4)	83.9 (60.8 to 94.4)	5.0 (2 to 14.6)	6.4 (3.4 to 19.9)	1.06 (0.78 to 3.07)	222.2 (105.2 to 264.7)
AC-8	2.0 (nd to 3.9)	6.7 (3.3 to 14.1)	2.2 (0.1 to 3.4)	0.3 (0.3 to 2.2)	0.04 (0.01 to 0.09)	24.5 (11.8 to 57.2)
AC-9	4.6 (nd to 11.3)	25.7 (1.1 to 44.1)	16.6 (0.1 to 24.9)	25.4 (0.3 to 56.2)	0.77 (0.49 to 1.95)	35.5 (14.2 to 332.1)
All	11.2 (nd to 190.2)	77.1 (1.1 to 331.2)	7.4 (0.1 to 68.4)	8.2 (0.3 to 87.3)	1.78 (0.01 to 19.52)	257.9 (0.3 to 1464.8)

Values given as medians with range in brackets
nd – not detected

3.2 Removal efficiency

The overall removal for each VSC is shown in Figure 3 as box and whisker plots showing whiskers from the 5th to the 95th percentile. Boxes are shown between the 25th and 75th percentile. Figure 4 shows the removal efficiency for each site.

Good removal was observed for hydrogen sulfide and methyl mercaptan across all AC systems. The exception being AC-8, which did not remove methyl mercaptan as well as the others, despite a higher contact time. This may be due to the inlet concentration of contaminants being lower than other sites, leading to a lower removal efficiency. This may also be due to the bulk of the media being activated alumina, rather than an activated carbon system.

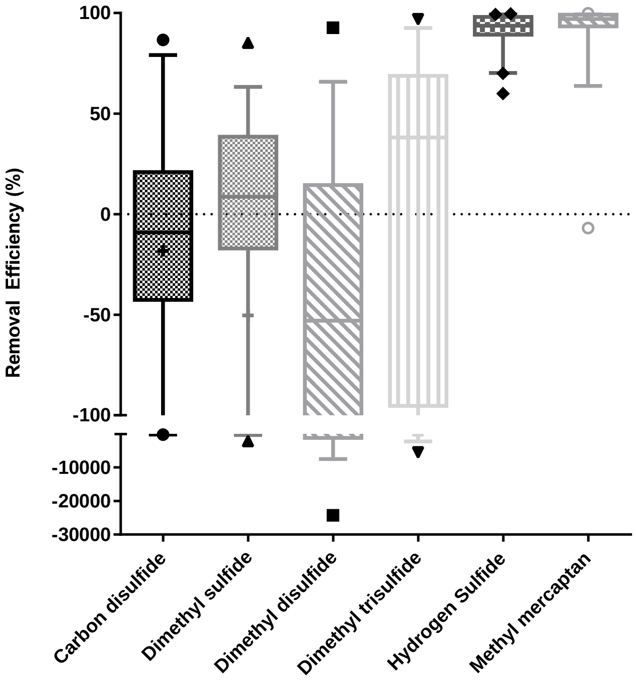

Figure 3: Overall removal efficiency

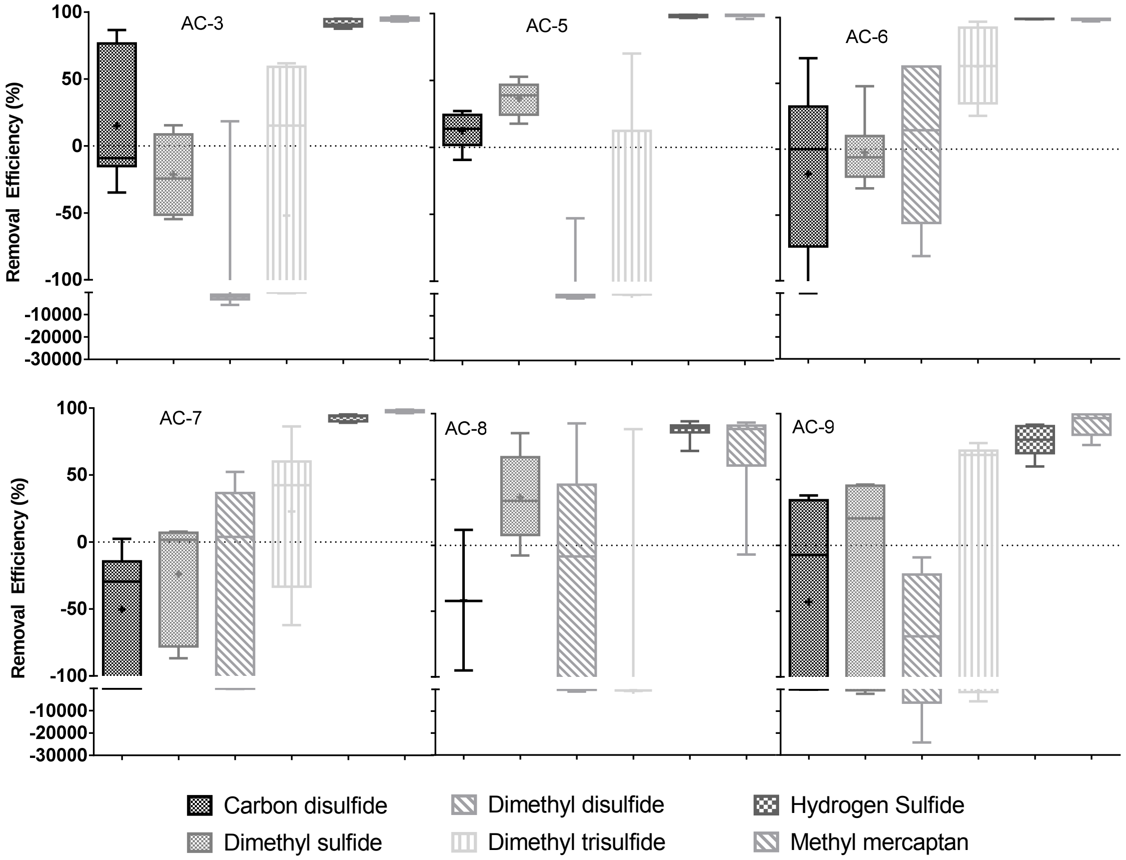

Figure 4: Individual removal efficiency

Dimethyl sulfide groups (including dimethyl sulfide, dimethyl disulfide and dimethyl trisulfide) were not removed as well as hydrogen sulfide and/or methyl mercaptan with frequent zero or compound release occurring. Dimethyl disulfide generation may be caused by the conversion of methyl mercaptan to dimethyl disulfide on activated carbon molecules (Bashkova et al., 2002). The caustic impregnated carbon performed better than the potassium iodide impregnated carbon with respect to dimethyl sulfide, and had a smaller range of removal efficiencies.

Carbon disulfide was found to have variable removal efficiencies from each unit as evidenced by the spread of the 25th to 75th percentile box. Caustic impregnated carbon provided a smaller range of removal efficiencies than the other types of carbon. The increased contact time in AC-7 and AC-8 showed little to no improvement in the removal efficiency of any of the VSCs identified.

3. Conclusions

AC systems for odour removal in sewer networks have been designed to remove the major odorant, hydrogen sulfide (Perez et al., 2010). The AC units under investigation removed both hydrogen sulfide and methyl mercaptan well. However dimethyl sulfide groups, particularly dimethyl disulfide, had low removal rates and were regularly generated or desorbed. As the dimethyl sulfide groups tend to have very low odour thresholds, this could lead to residual odours occurring from AC unit discharges. It is recommended that AC units for odour removal of sewer gases should be designed and provided to remove all known significant odorants, and that the design should cater for generated byproducts from the adsorption process.

Further research into the performance of AC units in cooler vs warmer periods, as well as the long-term performance of non-VSC compounds in installed systems is recommended.

Acknowledgments

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