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Impact of Sewer Emission Dynamics on Monitoring Campaign Design

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The emission of odorous compounds from sewer collection systems can cause social and environmental impacts on nearby or local receptors resulting in odour annoyance. A field study of short-term sewer emission dynamics was conducted to investigate the impact of sampling design on data accuracy and quality in order to improve odour monitoring design for assessment. Monitoring results indicated a strong diurnal cycle in terms of both odour concentration (OU) as well as the concentration of specific volatile organic compounds (VOCs) and volatile sulfur compounds (VSCs). Peak to trough odour concentrations varied by a factor of 1.5, while specific VOC and VSC concentrations had greater variability (peak to trough factors ranging from 2 to 10). 24 hour sampling showed that peak odour and specific odorant concentrations peaked at midnight, indicating that typical sewer sampling during conventional work hours would miss peak odour concentrations and underestimate the loading for odour abatement process design. This observation emphasises the importance of timing and understanding the diurnal emission variability in sample collection from sewer networks. Integrating understanding of sewer operational dynamics (hydraulics and air flow) into monitoring program design is essential to provide robust, representative data to support odour abatement processes design that provides reliable and cost effective odour solutions.

1. Introduction

Sewer networks are an important component of urban wastewater treatment systems that can be greatly affected by odour complaints (Wang et al., 2014a). A wide variety of volatile organic compounds (VOCs) and volatile sulfur compounds (VSCs) can be produced during sewage transportation due to the biochemical reactions under microaerobic and anaerobic conditions (Hvitved-Jacobsen, 2002). The composition of these sewer emissions depends on several factors such as the wastewater influents characteristics (upstream discharge types, stream flow rate, temperature of wastewater), metrological conditions (rainfall, ambient temperature, humidity) and the design of collection system (drain, manholes, lift station, mixing chamber) (Wang et al., 2014b). The accurate chemical characterisation of complex odour mixtures from sewer network is necessary in order to develop and/or select efficient emission abatement processes for improved sewer odour control (Sivret and Stuetz, 2012). To date emission studies of sewer systems has been based on a limited number of discrete samples or insufficient sampling events (Devai and DeLaune 1999; Wang et al., 2012), additionally, most odorous emissions studies have been focused at sewage treatment plants (Ras et al. 2008; Sheng et al. 2008) thereby providing a limited insights into the emission dynamics of sewer systems apart from information on the variability due to different catchments or from one country/region to another (Atasoy et al., 2004; Muñoz et al., 2010).

This study aims to characterise short-term sewer emission dynamics in terms of variations in odour concentration (OU), VOCs and VSCs in order to provide a better understanding of their impact on the design of the monitoring programs for sampling in sewer collection systems.

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2. Methodology

2.1 Sample collection and VOC analysis

VOC samples were collected by adsorption into Tenax TX (Markes, UK) sorbent tubes (with tubes being conditioned and verified contaminant free prior to use) using a calibrated air-sampling pump (SKC) at a constant flowrate of 100 mL/min for 20 mins to ensure that the correct sampling volume (2L) was collected. Thermal desorption (TD) (Unity, Markes, UK) coupled to an Ultra autosampler (Markes, UK) was used to desorb the samples. The sorbent tubes were heated and transferred onto the cold trap and injected into the gas chromatograph equipped with a mass spectrometer detector (GC-MS). The mass spectrometer was operated in continuous scan mode to allow the identification and subsequent quantification of as wide a range of VOCs as possible. The VOC analytical methodology is described in detail in Wang et al. (2012). The identity of VOCs was verified using reference standard, by initially matching the mass spectra with a mass spectrum library (NIST02 library).

2.2 Sample collection and VSC analysis

VOSC samples were collected Nalophan sample bags, with samples being analysed within 24 hours after the sampling events. Prior to sampling, sample bags were flushed with clean air to ensure that the bags were contaminant free. Sample bag were connected to an Air Server (CIA 8, Markes, UK) and pre-concentrated onto a specialised sulfur cold trap (U-T6SUL, Markes, UK) prior to injection. Sample analysis was performed using a gas chromatograph equipped with a sulfur chemiluminescence detector (GC-SCD) for the detection of hydrogen sulfide (H_2S), carbon disulfide (CS_2), methyl mercaptan (MeSH), dimethyl sulfide (DMS), dimethyl disulfide (DMDS), and dimethyl trisulfide (DMTS). The VOSC analytical methodology is described in detail in Wang et al. (2014a, b). H_2S was also analysed in situ by a portable analyser (Jerome 631X, Arizona Instruments, USA).

2.3 Sample collection and odour concentration determination

OU samples were collected in Nalophan sample bags. The OU determinations were analysed by dynamic olfactometer according to the Australian and New Zealand standard method (AS/NZS 4323.3 2001). All odour samples were collected in duplicate and measured on the same day as the chemical analysis.

3. Results

Long-terms emissions monitoring of sewer networks from two major cities in Australia, Sydney and Melbourne (Wang et al 2014b) has shown that temporal trends occur in the VSC concentrations of sewer atmospheres with the highest sulfur concentrations occurred either in the summer or spring, which is typically regarded as the warmer seasons. Figure 1 supports this observation and shows that for a commonly observed VOC (in sewer networks) such as toluene (Wang et al 2014a), higher concentrations were also detected in the warmer months. These long-term studies show that sewer emissions have large variability in terms of their seasonal dynamics and that this is most likely influence by the ambient temperature, however other environmental parameters and sewer conditions may impact concentration variability in sewer catchments.

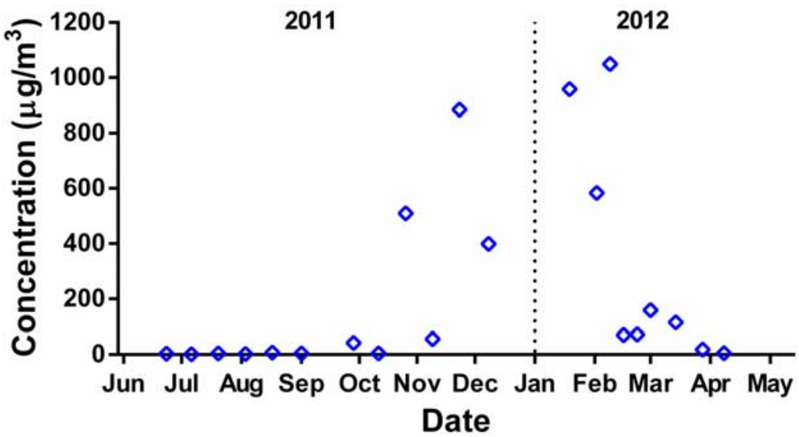


Figure 1: Long-term emission monitoring from the atmosphere of a sewer network showing variability in the concentration of toluene over a two years (2011 and 2012).

To provide a greater understanding of the influence of shorter-term sewer conditions (i.e. days and hours compared to months and weeks) on emissions variability, 24 hour sewer atmosphere sampling (to represent a typical diurnal hydraulic cycle of a sewer network) was undertaken at a sewer pumping station. Figure 2 shows the observed variability in H_2S and odour concentration (using 2 hour composite samples). The results show that the peak to trough odour concentrations varied by a factor of 1.5, whereas for specific compound concentrations such as H_2S (a common odorous compound typically described as rotten egg gas) had emission dynamics varying from 1800 to 6500 μg/m^3. Figure 3 supports this observation and shows that for two odorous VSCs (methyl mercaptan and dimethyl disulfide), the emissions dynamics varied between 250 to 450 μg/m^3 and 18 to 26 μg/m^3. Overall the emissions variability for a range of specific compounds typically detected in sewer atmospheres (in terms of peak to trough factors) ranged from 2 to 10. These short-term emission findings emphasise the importance of timing and understanding the diurnal emission variability in timing sample collection from sewer networks, as the maximum odour and specific odorant concentrations is peaking at midnight, sewer atmosphere sampling during conventional work hours would miss peak odour concentrations and underestimate the loading for odour abatement process design.

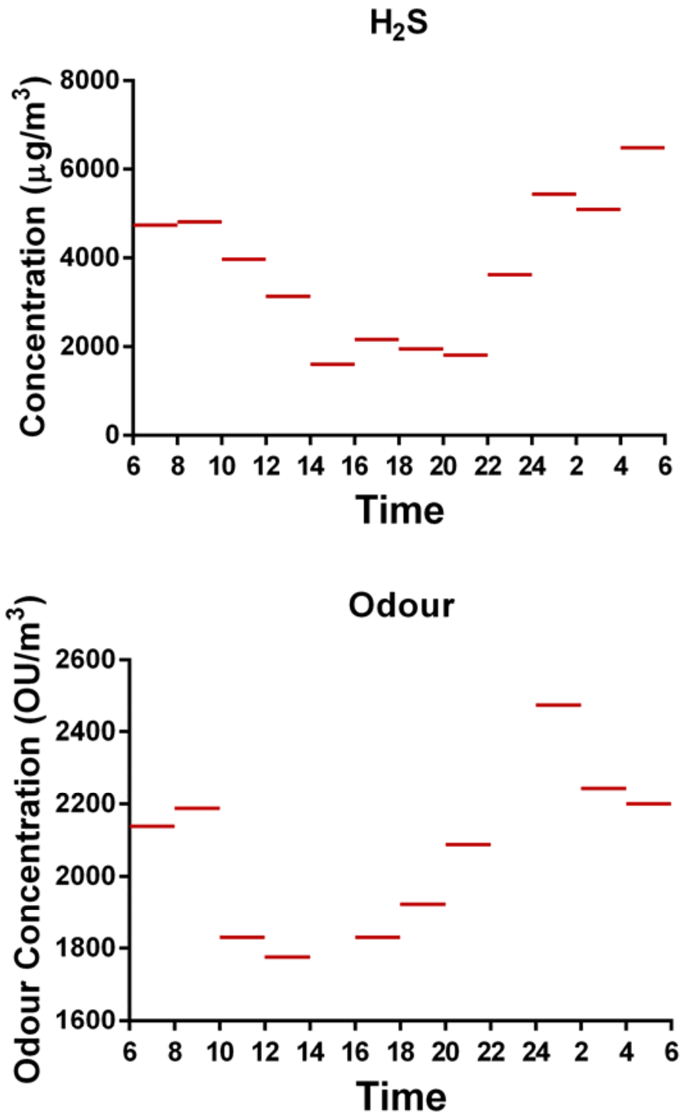
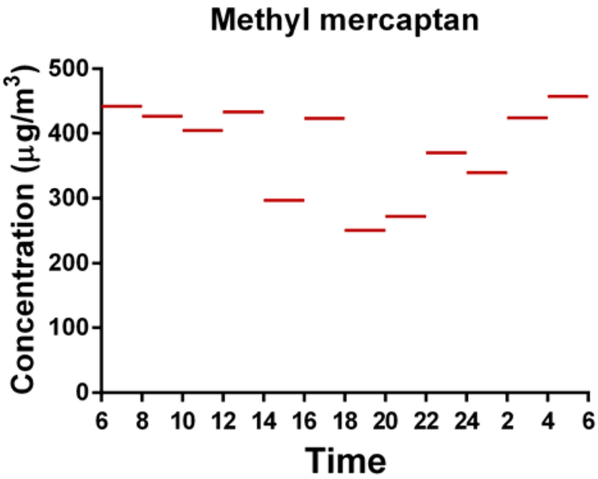


Figure 2: Short-term emission dynamics for H_2S and odour (as OU) showing 2 hour composite samples from a sewer pumping station.



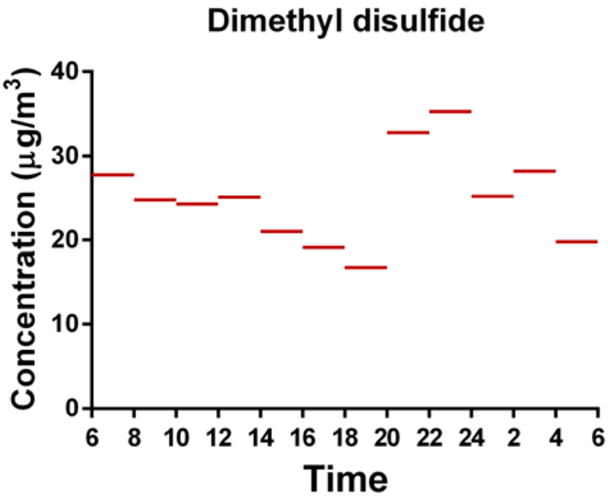


Figure 3: Short-term emission dynamics for a typical VSC (methyl mercaptan and dimethyl disulfide) showing 2 hour composite samples from a sewer pumping station.

The sampling duration (i.e. the amount of time over which a sample is integrated) is also an important consideration when assessing the emission variability in sewer networks in order to understand its impact monitoring sewer emission dynamics. Figure 4 shows the result of two different sampling intervals (using 10 min and 2 hour composite samples from a sewer pumping station) for a specific VOC (α-pinene) that is typically observed in sewer atmospheres. The short-term high frequency VOC sampling, demonstrates that in some highly dynamic time periods the concentrations between successive 10 minute samples can change by 50 to 100%. This finding suggests that the sampling duration could have a significant impact on data accuracy and quality and therefore influence how we design sewer monitoring programs.

Figure 5 shows the impact of a rainfall event of sewer emission variability. Odour concentration monitoring conducted during a rain event at a sewer pumping station shows a significant reduction in OU, demonstrating the effect that rainfall can have on odours present in the sewer headspace air and therefore the potential impact of abatement design criteria. Additional observations suggest that the sewer atmosphere will need time to recover to “normal” sewer emissions prior to sampling in order to determine representative emission data (in terms of odours and specific VOC and VSC).

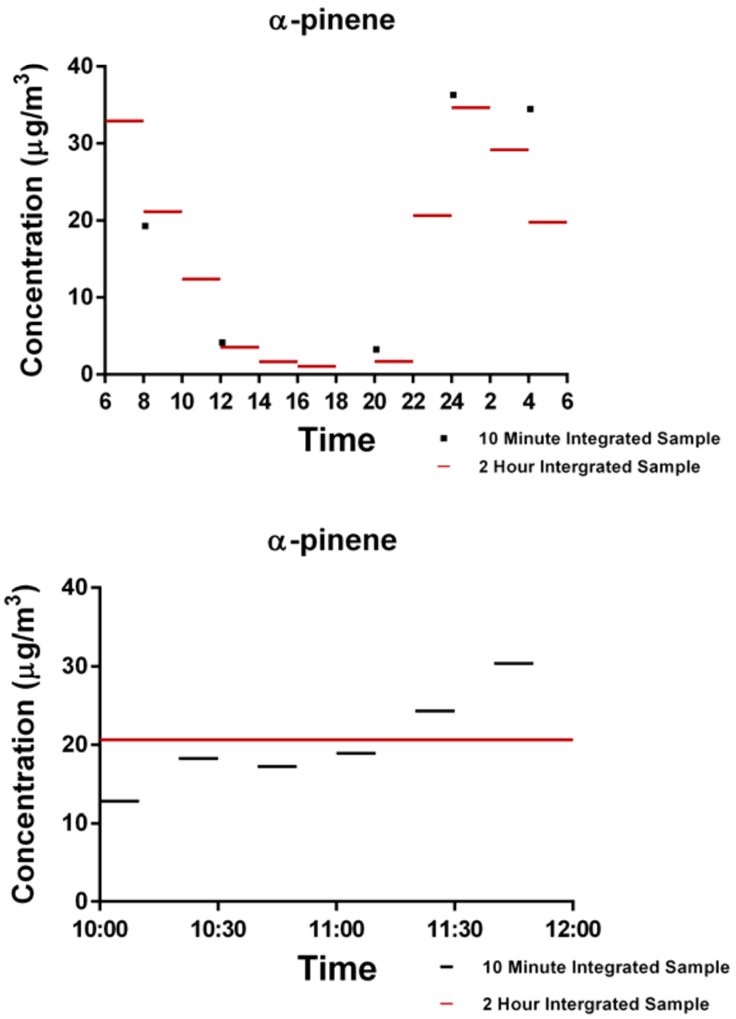


Figure 4: Short-term emission dynamics for a typical VOC (α-pinene) showing 2 hour and 10 min composite samples from a sewer pumping station.

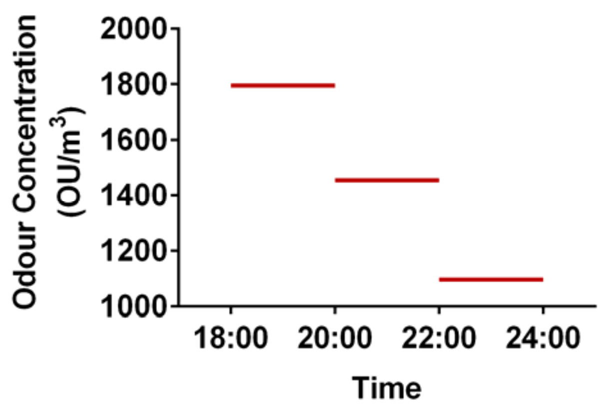


Figure 5: Impact of rainfall on emission dynamics for odour concentration (OU) showing 2-hour composite samples from a sewer pumping station.

4. Conclusions

Odour concentration (via dilution olfactometry) and specific odorant (VOCs and VSCs) concentrations in headspace air of a sewer pumping station were measured over a 24 hour sampling period to investigate the impact of a typical sewage diurnal cycle on sewer emission dynamics. The results showed that a strong diurnal cycle in terms of both odour concentration and the concentration of specific VOCs and VSCs were evident and that this would impact the sample timing and therefore our understanding of the odorous emissions in terms of emission variability for sewer networks. It was observed that peak odour and specific odorant concentrations occurred at midnight, whereas typical sample collection from sewer networks occurred during conventional work hours therefore missing the peak odour concentrations and significantly underestimate the emission loading for odour abatement process design. The sampling duration (amount of time over which a sample is integrated) was also found to be an important consideration as short-term high frequency VOC sampling demonstrated that in some highly dynamic time periods the concentrations between successive 10 minute samples can change by 50 to 100%. Additionally monitoring conducted during a rain event demonstrated the suppressive effects of rainfall on odours present in the sewer headspace air along with the need for a recovery period to re-establish "normal" emissions prior to sampling. The study emphasised the importance of understanding sewer dynamics to design a robust odour monitoring program (in terms of formation mechanisms, hydraulics and air flow) for sewer network assessment.

Acknowledgements

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