CHEMICAL ENGINEERING TRANSACTIONS
VOL. 68, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; **ISSN** 2283-9216

Implementation of a System for Rapid-response, Real-time and Predictive Management of Odorous Emissions from WWTP

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Thames Water is the largest water company in the UK serving nine million customers with potable water and treating the wastewater from 15 million customers in London and the Thames Valley. Thames Water implements a range of practices to minimise odour. Since June 2017, a system for the rapid response and preventive management of odorous emissions has been implemented at two large Wastewater Treatment Plants (WWTP) to a) drive improvements in odour performance and reduce customer impact by utilisation of real-time H_2S and predictive weather data on odour risk and plant performance and b) effectively evaluate and manage the performance of a WWTP that has recently been upgraded including significant investment (£24M) in odour control. At Deephams WWTP, Thames has committed to reducing the number of properties in the area most affected by odour, by a reduction of more than 99%. The real time odour monitoring is part of the odour management strategy and also helps to demonstrate to the economic regulator for the UK Water Industry that the objectives of the scheme are being achieved.

1. Introduction

The work presented herein evaluates the implementation/proof of concept (PoC) phase of a system for the rapid response and preventive management of odorous emissions at two large WWTP in the United Kingdom. Thames Water is the largest water company in the UK serving nine million customers with potable water and treating the wastewater from 15 million customers in London and the Thames Valley. Thames Water operates 351 WWTP that range in a population equivalent (p.e.) size between 5 and 3,300,000. Nearly all these WWTP are over 40 years old and were built to conventional open tank design. There are over 230,000 properties in the company's catchment within 1km of a WWTP. In addition, Thames Water operates 2,811 sewage pumping stations, some of which are located in central London. These facts illustrate the likelihood of impact of odours that escape from the sites (Winter *et al.*, 2015).

The need for operational and capital solutions to control and reduce odours is increasing because of a) increasing expectations from customers regarding quality of life and expectations from local authorities; b) expansions to WWTP to meet catchment growth and/or increasing quality requirements for effluent and c) pressure on land development. Thames Water operates in the south of England, a region where there is pressure to build houses, in particular on brownfield sites, making development of land adjacent to WWTP financially attractive.

Thames Water has used a formalised approach to odour management at WWTP since adoption of the 2006 Department of the Environment, Fisheries and Rural Affairs (DEFRA) Code of Practice (withdrawn in 2017) through the use of odour management plans for all WWTP over 10,000 population equivalent (p.e.) and larger pumping stations. The purpose of an Odour Management Plan (OMP), which is primarily a management guide, is to define how the potential and actual sources of odour are identified, and how, as far as is reasonably practicable, they are controlled and recorded. An OMP aims to identify risk and to quantify the impact.

There is a requirement for numerical data for the day to day management of WWTP as a serviceability indicator for stable operation, but also for strategic reasons; supporting a business case for capital investment, demonstrating outcomes of capital investment or other improvements and reviewing odour risk for potential development of adjacent land. It should be noted that a serviceable WWTP still may have an impact because of the inherent potential of odour from faecal matter; however the absence of effective serviceability measures was acknowledged by UK Water Industry Research (UKWIR, 2012). There have been limited publications on full scale real time measurements systems for odour in the field of wastewater treatment, although recent studies refer to developments and trials with electronic noses (Bourgeois et al., 2003, Deshmukh et al., 2015, Licen et al., 2018).

This project was part of Thames Water's strategy to reduce customer impact and part of the asset management plan odour investment stream in a specific programme aligning operational and IT strategy. It was managed by Thames Water's Intelligence Hub programme through an Odour Risk Management Business Development Appraisal (BDA).

The overall objective was to develop an operational decision support tool (DST) for odour risk management that would further embed odour monitoring into operational practice with the following benefits;

- Better understanding Thames Water's impact of odour on local communities
- Proactive response to odour before it becomes a problem
- Prevention of odour complaints related to WWTP
- Understanding of the effects of local meteorology on odour impacts
- Better informed decisions about any ongoing sensitive work and be able to use this data to validate odour complaints in the area
- Accurate inputs for real time monitoring, trending, analysis and investment planning.

2. Methods

In the BDA phase of this project, a two-phased approach was adopted in which the system was (1) commissioned and (2) operated as PoC DST at two of Thames Water's WWTP. As a result of a detailed procurement assessment, the consortium of Pacific Environment/OdourNet was selected as preferred supplier for this project. Their Envirosuite DST for pro-active odour management is a cloud based system accessible through all common web browsers which aims to deliver the following principal benefits:

2.1 Real time monitoring using H_2S sensors

This is one of the principal features of the DST. Data from H_2S monitors are continuously logged. Levels to trigger an alarm can be set according to the sensitivity of the site and accuracy of the H_2S sensors in use. When a trigger is exceeded, the DST produces an 'arc of influence' which is effectively the area the sensors 'see' taking into account on-line weather data (Figure 1). The arc of influence provides operators with an indication of the areas of the plant with a higher risk of H_2S emissions for focused trouble shooting.

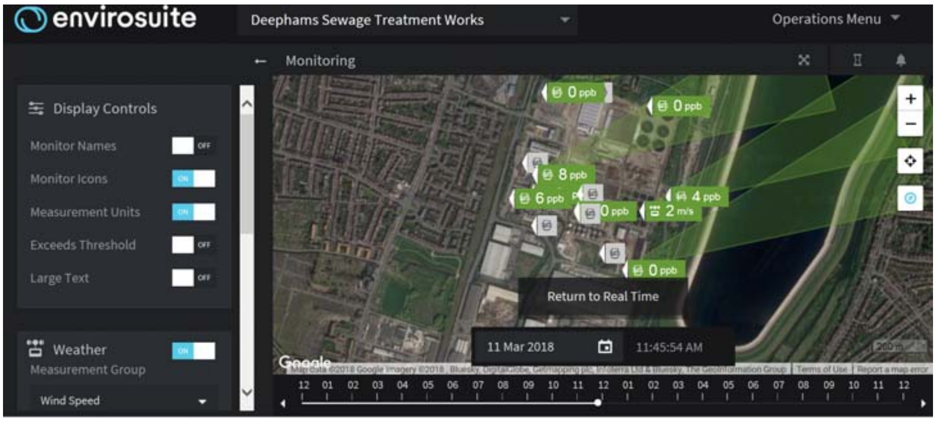

Figure 1: Monitoring H_2S in real time and 'arc of influence' indicating area for investigation

2.2 **Forecast and real time model**

The real time non steady state odour dispersion model forms a core part of Envirosuite system. It was configured to provide the following:

1. Real-time visualisation of the odour plume and on-site/off-site odour exposure concentrations to inform operators of the area where odour impacts may occur and provide an indicative assessment of impact risk based on criteria defined during the BDA.
2. Predictive assessment of impact risk for up to three days in advance using meteorological forecasts to assist in planning of any odorous activities (e.g. tank draw down, essential plant maintenance activities).
3. Historic analysis of odour exposure offsite over time periods that can be selected by the operator.

The models were established using odour emission data (in European odour units) collected from the sites during previous site odour surveys to ensure emission rates are defined in terms that are relevant to the development of human impact, and consider all sources on the site. The effect of source turbulence, which is a factor that can significantly increase odour generation in operations which handling odorous wastewater was also considered. Real-time data from the on-site weather station provided an accurate characterisation of local meteorology. The model therefore focused on assessing how odour exposure is likely to change due to variations in meteorological conditions around the site, which represents the most important influencing factor on odour exposure for any industrial facilities. Figure 2 shows a snapshot of the odour dispersion model.
Since odour emissions can be subject to complex dispersion patterns and WWTP are a combination of point sources and often non-buoyant area sources, it is essential that a model used to analyse or predict impacts in real time is able to accurately represent patterns such as drainage flows, inversions and recirculation**.** It is therefore critical that a three-dimensional, non-steady state modelling system is used. The model embedded in Envirosuite is based on a combination of the Weather Research and Forecasting (WRF), California Meteorological Model (CALMET) and California Puff Model (CALPUFF) models, which are, in combination, ideally suited to represent odour impacts from WWTP in real time and are globally recognised as best practice for situations of this type.

Figure 2: Example odour dispersion model for a six hour forecast

2.3 Odour risk forecasting and reporting

Odour risk forecasting on an hourly basis for proactive planning of potentially odorous on site activities is derived through outputs of the real time model (2.2 – output 1 and 2) and is provided in a format defined by the user e.g. provision of a daily risk report, which highlights with a traffic light system potential off-site odour impacts, and on an hourly basis for three days in advance. Forecasts beyond this timeframe are technically possible, but not typically useful for real-time operational applications. A suite of reporting tools for exporting data is available e.g. daily summary charts of monitored values could also be issued automatically to relevant staff.

2.4 Complaint verification through reverse trajectory modelling

Using data from the real-time weather station for wind speed, wind direction, solar radiation, temperature and relative humidity, allows the determination of the most likely source of an odour complaint within seconds of it being received. This model tracks a parcel of air backwards from the complainant post code over a set period of time to visualise if the odour could have originated from the premises in question according to the air movement.

2.5 The WWTP

Two operational WWTP were selected for the PoC phase lasting approximately 8 months:
Mogden WWTP is the second largest WWTP in the UK with a p.e. of 2.1 million. It is a sensitive site due to the size and age of the WWTP and proximity of housing. The WWTP, which has covered rectangular primary tanks, was upgraded in 2013 to extend sewage treatment capacity by 50% reducing the amount of storm sewage that overflows into the tidal stretches of the River Thames. Odour surveys using olfactometry are regularly carried out and the WWTP is regularly inspected by the local council, the London Borough of Hounslow (Winter *et al.*, 2015). The DST uses the array of existing H_2S sensors, which are 5 H_2S monitors (Jerome gold film adsorption) at the boundary and 8 of these sensors within the works taking readings at regular intervals.
Deephams WWTP is located in Edmonton, north London and currently has a capacity of 885,000 p.e. (Robins, 2015). An upgrade that is currently underway will increase this capacity to 989,000 p.e. (ibid). The real time odour monitoring is part of the odour management strategy and could also help to demonstrate to the Office of Water Services (Ofwat), the economic regulator of the UK Water Industry that the objectives of the scheme are being achieved. The upgrade includes an expenditure of around £24 million on odour control, which is expected to reduce the number of properties most affected by odour from the WWTP by 99 per cent. At Deephams WWTP, the H_2S sensors used for the DST are solar powered Cairpol electrochemical sensors, communicating via 3G communication directly to the cloud based server. These sensors are less expensive compared to the Jerome sensors allowing an array of 15 sensors to be employed within budget. However, the Cairpol sensors are also less sensitive; good as an indicator of change, but the absolute number at the low ppb range need to be treated with caution. However, it should be emphasised that Envirosuite is sensor 'agnostic' and offers the flexibility to add in other sensor types as and when they become available.
Regular stakeholder meetings were held throughout the PoC phase to review site specific requirements and existing process for management of odour risk, focusing on;

- Management of odour complaints and type of data available for investigation
- How monitoring of H_2S was being used to manage odour on site
- Frequency of automated reporting requirements, who should receive them and in what format
- Dashboard displays and who should see them
- Availability of existing modelling data
- Current arrangements in place for monitoring and measuring odour performance on site

This continued engagement process with operations and site management contributed significantly to the success of the project as the user of the DST was fully embedded in the PoC of the project.

3. Results and discussion

Both WWTP had different drivers for implementing the DST. Mogden WWTP is a sensitive site and operators are attuned to odour management as a priority of the routine site operation. Therefore the DST was trialed for further embedding odour management into operation practice through utilisation of the reporting tools and the complaint verification feature. An example is the data availability report shown in Figure 3, which records the availability of the sensors with reference to the expected readings. The target is 90% availability as the gold film sensors are not available during regular regeneration intervals. This can be useful information when demonstrating robustness of site monitoring to external stakeholders.

Figure 3: Data availability report

Another useful report (not shown) is the odour risk forecast which gives the operator visibility of the weather conditions and the risk of odour impact. This allows the site operator to assess if potentially odorous activities e.g. sludge movements can be carried out or should be deferred if possible.
Deephams WWTP focused on trialing the system primarily within the control room. The major plant upgrade has further reduced odour impacts and the site management is primarily using the system as an on-demand analysis tool that can be used when detailed analysis of odour issues is required and in the future in providing supporting evidence that the recent upgrade has been beneficial for the site, or shows that the site is being managed well. The overall construction project at Deephams started in 2013/4 and is expected to finish in 2018 (Brockett, 2017). Figure 4 shows monthly average H_2S trends in 2017 and 2018 derived from the DST. The consistently lower average H_2S levels in 2018 until April compared to 2017 demonstrate some of the benefits of the scheme and a consistent reduction of impact. It should be noted that the 2017 data do not present the 2010 baseline prior to start of the construction project hence the reduction appears relatively small because it does not represent the complete reduction of impact.

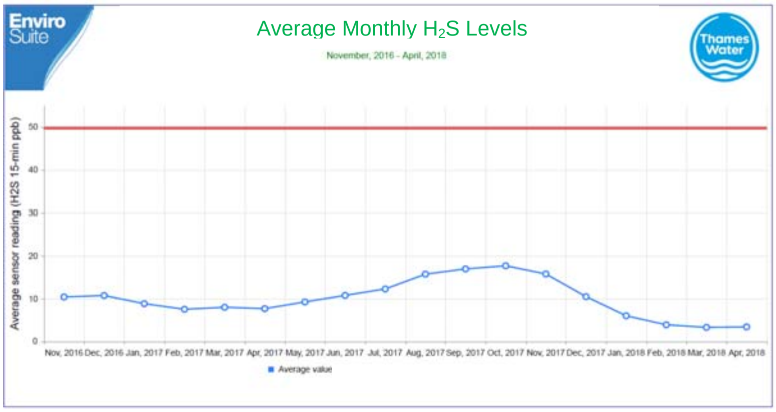

Figure 4: Monthly average H2S levels 2017 and 2018 at Deephams WWTP

3.1 Sensor technology

The Envirosuite DST is sensor agnostic. At Mogden WWTP, the existing arrangement of Jerome gold film H2S sensors was ideal for use in the DST. The existing alarm threshold of 15ppb H_2S was adopted in the new DST. However, a challenge was to align two on-site data servers in order to avoid data gaps. Previously, this was done by manual intervention which is not suitable for a fully automated cloud based system. An ideal solution would be to transmit data independently via dedicated data loggers to the DST without utilisation of the site Supervisory Control and Data Acquisition (SCADA) system. This solution is currently being considered for application at the WWTP.
The Cairpol sensors used at Deephams WWTP have not previously been integrated with the Envirosuite platform. Review has found that these have performed well but some sensors deteriorated after 6 to 8 months use, opposed to the expected one year lifetime. With reduced sensor data, the system still provided meaningful data indicating the potential to reduce the number of sensors from 15 to 10. At the low ppb range, the H_2S sensors showed to be adequate as an indicator of change, which is important for the monitoring aspect. However, the absolute readings needed to be treated with caution. It was therefore decided to set the alarm level for this system to 50 ppb H2S to have confidence that measured levels are representative of significant changes in H_2S.

3.2 Benefits

The DST was tested as proof of concept at two WWTP. As such, financial benefits cannot be claimed at this stage. However, the DST provides information that helps decision makers make better and more efficient decisions. An improvement in effectiveness and efficiency in the odour management context would mean that:

- Decision makers are able to undertake the same tasks (e.g. deal with complaints) in less time or with fewer resources
- Odour impacts that may have otherwise occurred are avoided because they can be predicted

- Activities to manage odour that are not effective but have a cost to the business, are also avoided

Therefore, the DST essentially allows an 'optimisation' of decision making – i.e. by supporting decision making that leads to a more optimal set of outcomes, including reduced odour impacts on the community and lower costs of operation. Figure 5 shows a framework for potential benefits of the DST.

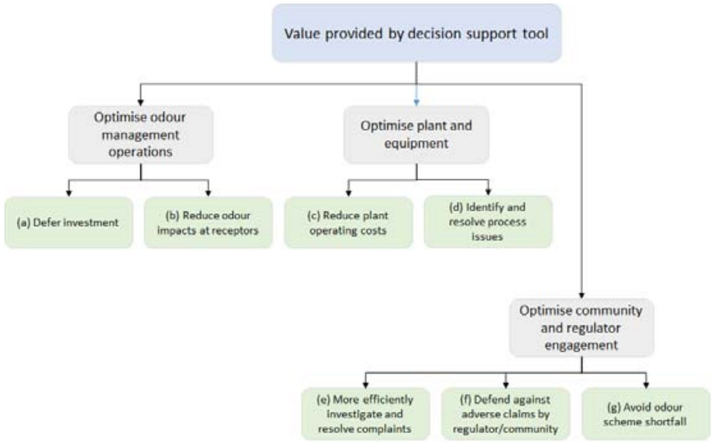

Figure 5: Framework for potential benefits of the DST

4. Conclusions

The DST has been successfully implemented at two large WWTP in the UK. The principal features of the system are odour monitoring, modelling, complaints verification and reporting. The financial benefits of a DST cannot be assessed at the end of a proof of concept project. However, the DST provides intangible benefits such as optimised odour management, optimised plant and equipment and optimised community and regulator engagement which, ultimately will lead to monetary benefits. The choice of sensors for monitoring depends on the site sensitivity and financial constraints.

Acknowledgments

The views expressed in the paper are those of the authors and not necessarily those of Thames Water. The authors would like to thank Thames Water and Envirosuite for permission to publish this paper. We would like to thank Chris Mckenna and Richard Dennet of Thames Water operations, Steve Wilson and Rod Kerr of the Deephams upgrade project team and Nick Jones of OdourNet for all their support during the project.

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