ODOUR MEASUREMENT AND CONTROL

Odour from waste-water treatment works and other operations such as waste facilities is a perennial problem particularly for those sites with houses nearby. As urban areas have expanded, pre-existing facilities on the edge of towns and cities have been surrounded by residential areas, bringing odour problems closer to people. Heatwaves increase the intensity of odour as temperature (and humidity) increases the evaporation of molecules, so odour problems may worsen with climate change increasing the frequency of extreme weather. Added to this, the regulation of pollution typically becomes stricter over time and communities demand more from regulators and industry. In the UK, a statutory nuisance abatement notice can be served by the local authority which can severely limit how a site is operated. Abatement notices stay in place with the site indefinitely. In addition, water companies are driven by the Ofwat service incentive mechanism to reduce complaints logged from customers, or face a reduction in their "Ofwat score". As the adage goes you can only control what you can measure. Accordingly, businesses have increased their expenditure to control and track odour impacts. But what is the definition of odour pollution? And how can it be measured, modelled and controlled?

Odour pollution is defined as 'an offence to the senses'. In terms of regulation taking England as an example, the Environment Agency (EA) regulates waste sites and installations through permits to control environmental impacts. Environmental impacts, including odour incidents, are assessed and scored under a 'Common Incident Classification Scheme (CICS) using guidance (Box 1).

"There is an element of judgement by EA officers when assessing incidents [under the CICS] using the guidance framework, but the difference between a category 1 and category 2 odour incident is very obvious," says Nick Sauer, Technical Advisor on waste at the EA.

Any potential breaches of permit conditions are assessed and scored under a Compliance Classification Scheme (CCS). Under the environmental permitting regulations there are two objectives that are relevant to odour. The first is that Best Available techniques (BAT) must be used to prevent, or if that is not possible, minimise pollution. (Across Europe the Industrial Emissions Directive (2010/75/EU) requires that BAT be implemented to prevent or at least minimise pollution.) The second objective is that unacceptable pollution must be prevented. If unacceptable pollution is caused and cannot be mitigated, then the EA has an obligation to revoke the permit for the site or installation. The EA can also refuse to permit sites where unacceptable pollution is anticipated.

In England, activities that cause odour are also regulated by the local authority, through statutory nuisance provisions under the Environmental Protection Act 1990. The local authority will issue a notice to control any activities, not just permitted sites, that cause a statutory nuisance. If a company or individual does not comply with the notice then the local authority can take enforcement action. For sites permitted by the EA, local authorities are required to obtain permission from the Secretary of State before they can take enforcement action to avoid dual regulation by both the EA and the local authority.

Operators of facilities at risk of odour incidents can use monitoring (or modelling) to prevent complaints, achieve and prove their compliance with their permits, and defend themselves against odour complaints, to prove what the ambient odour levels were and/or that the odour originated elsewhere for example. Odour can be monitored at site boundaries or on site where odour control systems expel air. Various technologies are available, at a

Box 1: Common Incident Classification Scheme (CICS) Environment Impact Scores © Environment Agency, 2020

Category 1: Major serious, persistent and/or extensive impact or effect on the environment, people and/or property.

Category 2: Significant impact or effect on the environment, people and/or property.

Category 3: Minor or minimal impact or effect on the environment, people and/or property.

Category 4: Substantiated incident with no impact. EA officer attended but no complaints were received.

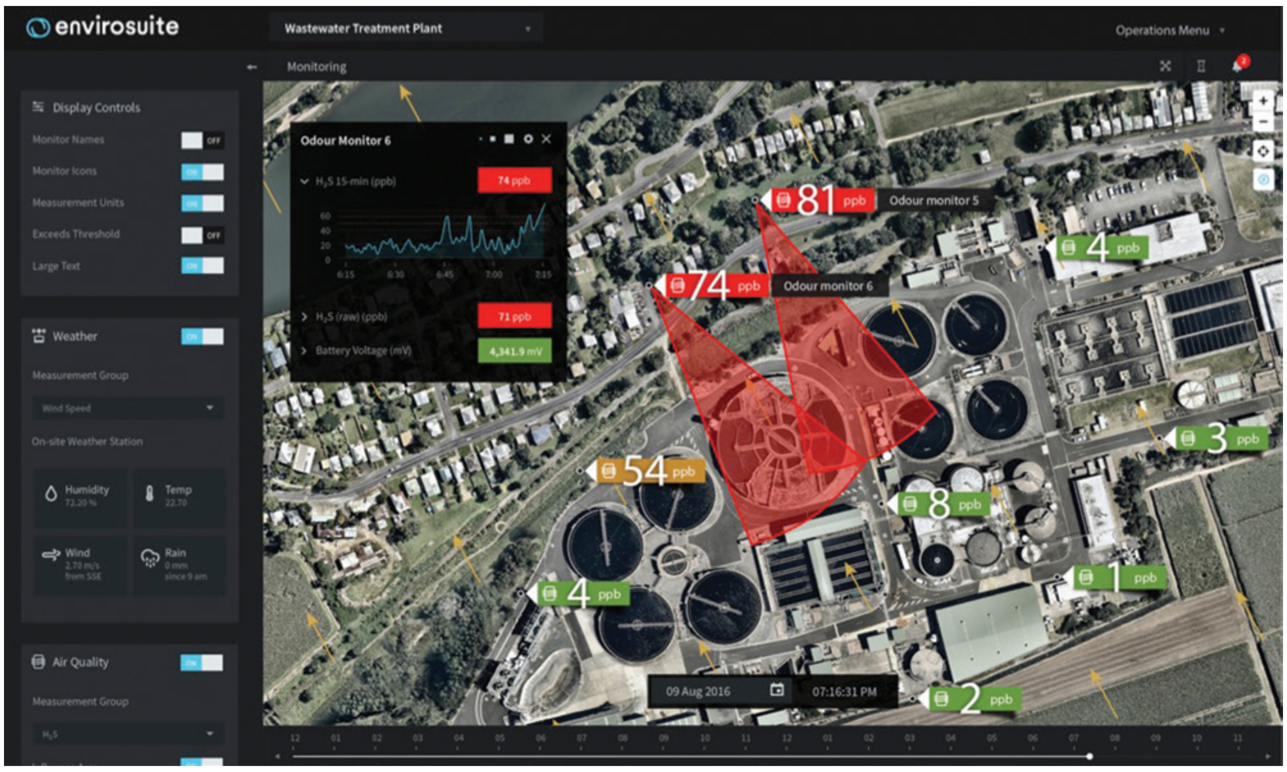


Figure 1: Dashboard for a modelling software platform © Envirosuite, 2021.

Box 2: The advantages and disadvantages of different odour measurement technologies

Measurement technology	Advantages	Disadvantages
Test kits, lab analysis	Cheap | Good at high ranges >20 ppm	Not continuous | Time lag before results | Not good at low ranges <5 ppm | Not great in wastewater
Redox, or Oxidation Reduction Potential (ORP)	Relatively cheap	Not specific to H_2S | Difficult to maintain | Not accurate at low concentrations of H_2S | Difficult to correlate Redox to H_2S; not a strong relationship between ORP and H_2S
Gas detection	At best gas detection is an indicative measurement of dissolved H_2S.	Relationship between H_2S and wet well is not fixed due to fluctuations in pH because of anaerobic conditions | Turbulence affects readings | Temperature changes affect readings | Cannot control all the factors involved.
An innovative gaseous/ aqueous technology to monitor H_2S	Non contact therefore no fouling, Continuous sampling of water using a pump and sulphuric acid reagent to liberate H_2S gas for measurement., Accurate measurement at low concentrations of H_2S	Relatively expensive | Operational costs to replace buffer, tubing, calibration of sensor
UV analysers	Measure concentrations in ppb, Most accurate for measurement Can have flows from different directions, so can measure multiple sample points simultaneously	Most expensive odour or H_2S monitoring technology | Not suitable for exposure to weather so need to be housed in a kiosk | Not ATEX approved for gas streams
H_2S analyser using gold leaf sensor	Portable unit but can be adapted for use for fixed monitoring Measures concentrations in ppb	Expensive | Odour monitor – not specific to H_2S | Cross sensitive to other gases | Not ATEX approved for gas streams
Paper tape units	Measures concentrations in ppb, H_2S specific, Readings are often an average over a 15 minute sampling period	Expensive: need to buy tape and pay for operator to maintain on monthly basis | Moisture or water can discolour the tape | Cannot distinguish between tape discolouration caused by factors other than H_2S (e.g. moisture, gas, water or relative humidity) | Not ATEX rated for gas streams
Electrochemical cells	Cheapest solution | Can monitor in a stack with regular flushing with fresh air – works well in dry air streams	Does not measure down to ppb, typically measures gases down to ppm for H&S room monitoring, portable gas detectors | If differential pressures are used to create airflow, the cell can fill up with water and destroy the sensor. | Electronic noise interference because amplify electronics to read at low concentrations | Cross sensitive to other gases | Cross sensitive to temperature changes | Interference from water or high relative humidity. | Not ATEX rated for zoned gas streams
Innovative H_2S sensor	Sampling and conditioning to remove any interference from water and high relative humidity. | Monitors ambient temperature and environmental conditions and gas changes to calculate and remove any electronic noise interference | Solves the above traditional disadvantages for electrochemical cells except cross sensitivity. | Can measure pre and post odour control simultaneously	Cross sensitive to other gases requires suitable sampling and conditioning and/or ATEX safety devices if monitoring an ATEX air flow.
Innovative H_2S sensor for monitoring wet stacks	Pre-calibrated for ease of use Extra membrane provides protection from moisture Low maintenance, can be validated by the user Sensors can be removed for calibration and reused on rotation | Sensors only need replacement every 2-3 years | No moving parts No need to bring the sample to the sensor via sampling systems | Smart sensor technology | Relatively low cost | High performance | Measures down to 1 ppb	

Table 1: The best technologies to monitor odour versus hydrogen sulphide

Odour monitoring	H_2S monitoring
UV analysers	UV analysers
H_2S analyser using gold leaf sensor	Paper Tape
Electrochemical cell	H_2S analyser using gold leaf sensor (if no mercaptan gases present which are cross reactive)
	Electrochemical cell if no other odours present

range of prices with different advantages and disadvantages (Box 2). When designing an odour monitoring plan, Peter Holbrow, MD at Pollution Monitors, points out the questions that an operator needs to ask themselves:

"Besides deciding whether to monitor at the boundary and/or at the odour control unit, operators need to ask themselves other questions. What are the conditions for monitoring? Is there wet or dry air flow in the odour control stack to be monitored? Is the air flow zone rated reference the ATEX Directive? If so, to what classification?" It is worth getting expert advice on where to site sensors or monitors to ensure compliance with the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) and EU directive on 'ATmospheres Explosible' (ATEX) 137 and therefore avoid gas explosions, recommends Mr Holbrow, who continues, "Other fundamental questions when choosing monitoring technology will be: what are the expected gas concentrations for any gases that are present? What is the purpose of the sensor or monitor? And what is a reasonable budget?"

Another key question is whether to monitor 'odour' in general or hydrogen sulphide more specifically, which will narrow down which technology to use (Table 1). Problematic odour from wastewater is mostly caused by hydrogen sulphide (H_2S), which can also cause corrosion of pipes – so by reducing this gas companies reduce corrosion of pipes as well as odour issues. Precise and accurate measurement of hydrogen sulphide can be used to control chemical dosing for wastewater treatment plants.

"Removal of hydrogen sulphide often involves expensive chemicals or expensive hydrogen peroxide," explains Tristen Preger, Director of OEM Sales & Business Development at ATi, "and continuous measurement of hydrogen sulphide in wastewater is notoriously difficult."

Any sensor, monitor or analyser will need recalibration and servicing. "A legal defence under an operator's Odour Management Plan will only be valid if equipment is working and data is reliable," points out Mr Holbrow.

"Any system is only as accurate as the person maintaining and calibrating it," adds Mr Preger.

Odour sensors will need maintenance every 6-12 months. Most manufacturers recommend recalibration every 6 months. Operators can run a few checks themselves to keep things in good working order.

Real-time odour monitoring data can be used in a modelling platform

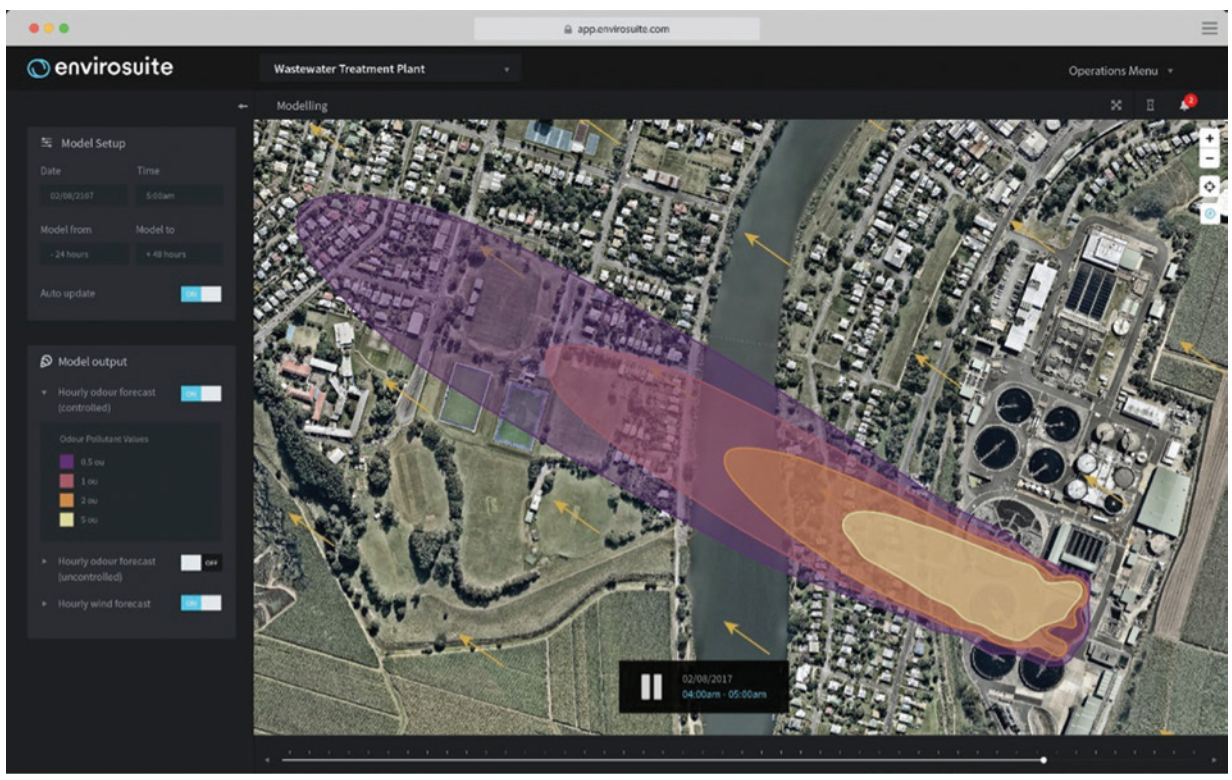


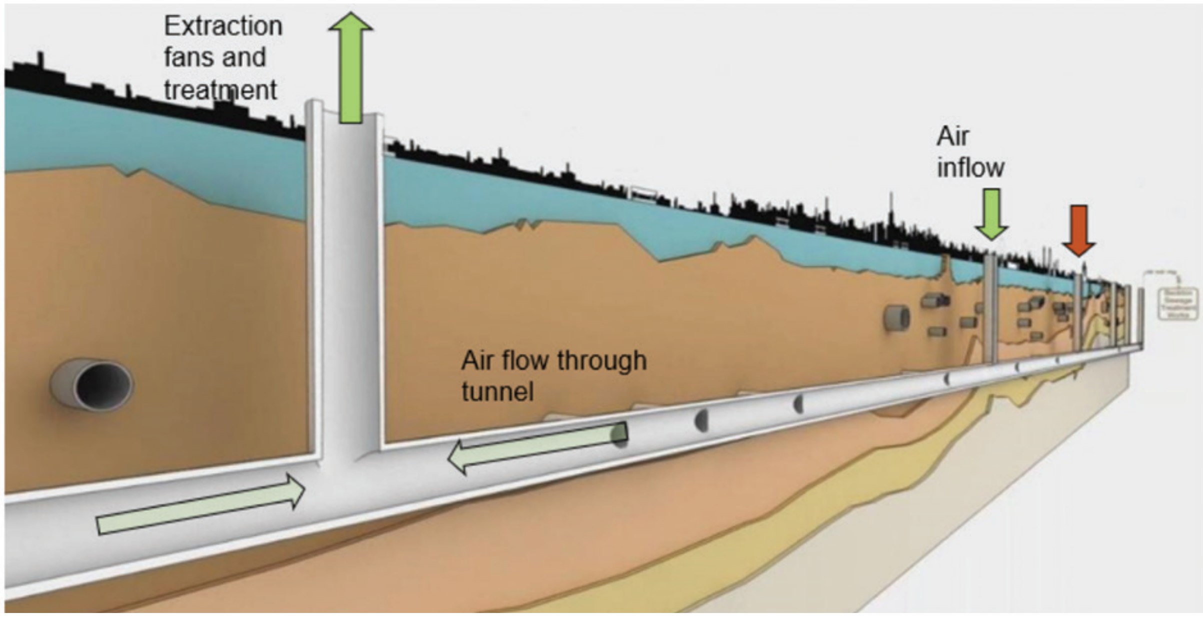
Figure 2: Predictive dispersion modelling © Envirosuite, 2021.

to gain further insights from the data by combining it with site specific information and meteorological data. A modelling software platform can take real-time monitoring data from a range of sensors, meteorological satellite data and an onsite weather station to generate an arc of influence for each device, enabling the identification of the source in real-time. Where two (or more) of the arcs overlap this helps identify the source of the odour that has been measured on affected monitors (Figure 1).

Real time alerts can be created tailored to an operator's needs, aiding in the understanding of when an event is developing rather than receiving the data after it has already passed.

By using a sensor agnostic software platform, multiple parameters can be made available onto one dashboard, for example numerous gases (hydrogen sulphide, ammonia, sulphur dioxide), noise, water quality, network sensors and groundwater flow (Figure 2). Historical and predictive metrological information can be combined with innovative dispesion modelling to predict where and when odour problems may occur. Therefore, modelling can be used to provide an early warning of odour issues

Figure 3: High level dashboard for a modelling software platform © Envirosuite, 2021.



Ventilation of the Thames Tideway Tunnel, from Georgaki et al, 2018.

and enable the operator to respond rapidly. The same forecasting models can be used to generate an odour risk forecast for the next 72 hours, so that operational tasks can be altered or reconsidered, to help reduce the risk of the facility impacting the local community. Should offsite complaints be registered, reverse trajectory modelling (back tracking) can be deployed to model the parcel of air from the complaint back to the likely source of the odour. Therefore, reverse trajectory modelling can be used to narrow down the focus of investigations into the source of a historic odour problem.

A higher-level dashboard can be used to summarise Key Performance Indicators (KPIs) on a single interface, for example threshold breaches and odour complaints, to present the headline data to management or to site managers (Figure 3).

Besides chemical dosing, another way to control odour is to incorporate preventative measures at the design stage.The Thames Tideway Tunnel (TTT) project in London, has incorporated a ventilation and odour control system to mitigate the potential risk of odour nuisance in the vicinity of tunnel shafts. For this reason, an Air Management Plan was developed which defines how air from the proposed TTT is vented in and out of the system and how air releases are controlled and treated. Activated carbon filters were chosen for use in ventilation shafts to trap odours. Another incorporation in the design of the TTT project is the use of high ventilation columns to discharge foul air at height, to prevent the impact of odour to the surrounding area and minimise the risk of odour complaints. To allow for the proposed air management and odour control system to be sized, extensive research and development work including a series of field trials to determine the impact of septicity during tunnel operations, hydraulic modelling studies, air movement modelling and dispersion modelling studies were undertaken as part of the TTT project. Overall, the TTT air management system designed achieves over 99.7% treatment of typical year exhausts. Once operational, the TTT will use hydrogen sulphide sensors to monitor odour at all shafts to ensure system efficiency.

"We undertook field trials including a review of commercially available hydrogen sulphide monitors," explains Dr Sofia Georgaki, Odour and Ventilation Lead for the TTT Air Management System, "we discovered that detection of hydrogen sulphide at low concentrations is difficult due to several issues identified during the TTT trials. Some of the issues include power requirement, difficulties in transmitting the data and maintenance of the equipment but also sensitivity of most sensors available to ambient temperature and humidity." To overcome the problems identified, the team designed their own bespoke self-powered solution combining a H_2S analyser (using a gold leaf sensor) with solar panels and telemetry.

To conclude, compliance with an odour monitoring plan is a vital first step, but you cannot rely solely on monitoring to reflect reality, and the human receptor is always paramount. "You can use surrogate measures to monitor odour," explains Mr Preger, "but should always recognise that nothing is better at picking up issues than the human nose."

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