Paper 5 - ODOURS AND SEWAGE TREATMENT

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Introduction

The common public perception is that anything to do with sewage treatment must smell horribly and yet as those in the business know, many miles of sewers and a large number of treatment plants are operated with no odour problem. On the other hand there are a significant number of odour problems. With a few exceptions, these would appear to be genuine, with defined and measurable reasons for the problem and in most cases with identifiable solutions.

The underlying causes of odour associated with sewage are well understood in principle. Respiring micro-organisms, feeding on organic matter, consume oxygen dissolved in water. Once the system is depleted in oxygen, the same or different organisms turn on alternative metabolic pathways, first using nitrate as an alternative electron acceptor to oxygen, then turning to sulphate and finally carbonate, producing in turn nitrogen, hydrogen sulphide (H_2S) and methane. H_2S is highly odorous and one of the main culprits associated with sewage related odour, though many other highly odorous compounds are also formed in the resulting anaerobic conditions following oxygen depletion. These include mercaptans and other small organic molecules containing sulphur atoms, ammonia, amines, volatile fatty acids and others. Indole and skatole, resulting from the breakdown of proteins are responsible for faecal odours.

A lesser number of odour problems are caused directly by the discharge of odorous material by industry. More commonly, industrial discharges, by virtue of their strength, temperature or sulphate concentration, simply accelerate the production of the range of biogenic odours described above.

Measurement of odour

It is relatively easy to measure H_2S. The gold film monitor, for example, is a hand held device that will respond to H_2S, by detecting a change in the resistance of the gold film, down to the part per billion, ppb, level. The threshold odour concentration of H_2S, effectively its limit of detection by the human nose, is a little under 1 ppb. It could be misleading however to rely totally on H_2S as a surrogate odour measurement. The ratio between H_2S and odour is very variable, not least because the volatility of H_2S is hugely influenced by the pH value and presence of heavy metals, such as iron, in wastewater. Some treatment systems are specifically aimed at H_2S and not surprisingly they also affect this ratio. Nor is it really possible to get a better handle on quantifying odour simply by adding more compounds to the list for detection. The possible list is too large, costs rapidly escalate nor is there any method of estimating odour strength from the concentrations of such a list of compounds.

An alternative procedure for measuring odour strength is olfactometry. This relies on a panel of trained human sniffers (trained in the test procedures, not trained to have sensitive noses). A sample of odorous air is successively diluted and fed to the panel. The odour strength of the air is equal to the number of dilutions at which only 50% of the panel can still detect odour. It is given units of odour units per cubic metre, ou/m^3 . One odour unit is the amount of odour contained in 1 m^3 of air, whose odour is just detectable by 50% of the panel.

Though olfactometry relies on the subjective response of the human nose, it is the nearest approach to an objective measure of odour. It is now the subject of a European Standard. It says nothing about the quality of an odour. While quality or hedonic tone is obviously an important property of an odour, there is evidence that strength is the single most important factor for dilute odours at their limit of annoyance. There are few wastewater related odours which if detectable can be ignored because of their pleasant quality.

Olfactometry has one significant drawback - its sensitivity. A practical limit of detection is in the region of 20 ou/m^3, though some laboratories usually do not quote below 70 ou/m^3. In addition background air samples, with no obvious quality problems, generally have odour strengths in the region 20-100 ou/m^3 or even higher. An unpleasant odour, however, is believed capable of causing nuisance at five times its threshold odour concentration, equal to an odour strength of 5 ou/m^3. In other words olfactometry cannot be related directly to the presence or absence of nuisance. Olfactometric measurements cannot be used for surveying large areas to determine the impact of odour. Their main strength lies in characterising odours where they are strong, close to sources, and for assessing the efficiency of odour abatement equipment.

In the field of odours derived from sewage treatment it is also desirable to have a measurement for the amount of odour associated with wastewater. WRc, building on work performed at Bradford university, has developed a test known as the odour potential. This is the odour strength in ou/m^3 of air blown through a liquid sample in a standard apparatus. The odour potential can be used to follow the development of odour through a collection system and treatment works, and observe and predict the effect of returning highly odorous sludge liquors within a process. It is also central to a method developed by WRc for estimating impact due to odour. WRc has measured odour potentials at over 30 sewage treatment works and built up a data base of typical values such as follows:

- fresh crude sewage	- up to 5,000
- settled sewage	- up to 20,000 (very much higher if tanks not effectively de-sludged or if flow includes added return liquors
- activated sludge mixed liquor	- 2,000 (nitrifying) 5,000 (non-nitrifying)
- final effluent	- up to 2,000
- crude sludge and sludge liquors	- up to 5,000,000
- digested sludge and sludge liquors	- up to 200,000
- raw sewage plus return liquors	- up to 70,000
- significantly septic sewage (H2S > 1 mg/l)	- around 100,000
- intensely septic sewage (H_2S > 10 mg/l)	- up to 1,000,000

While odour strength and odour potential are very important parameters, they do not directly address the most important question - how much odour does a source or process give off? This is given by the odour emission rate in odour units per second, ou/s. For an enclosed process emitting air via a vent, this is simply equal to the air-flow-rate in m^3/s times the odour strength in ou/m^3. For open processes, as found in most sewage treatment works, estimation of the odour emission rate is much more difficult. There are existing techniques but none are wholly satisfactory. It is possible to measure a number of odour strengths downwind of a process and then use a technique to back-calculate the odour emission rate that was responsible. However this is expensive and the odours sampled are already dilute and difficult to measure. It is possible to measure the odour strength of air blown through a hood floating on an open tank. This is restricted to simple processes, frequently does not generate odours significantly different from background and is very prone to contamination. These uncertainties are then greatly magnified by an enormous scale-up factor from the area of the hood to the area of the process.

WRc has taken a different approach. This involved the construction of an environmental wind tunnel. Process modules were placed inside the wind tunnel. This allowed for direct measurements of odour emission rates and a means to investigate the factors responsible.

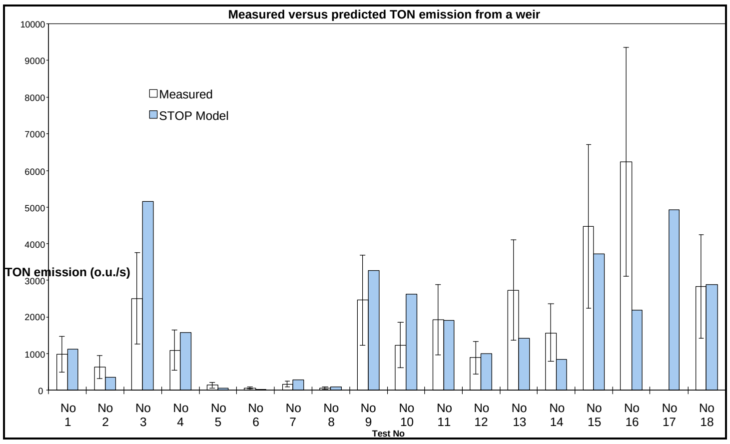
In all cases odour emission rates were directly proportional to the odour potential of the liquid in the process. In addition there were a number of process specific parameters such as

- wind-speed (significant for open tanks, not for highly turbulent processes)
- area
- length (of weir, channel, distributor etc.)
- height of drop (over weir, falling from pipe)
- flow-rate (for weir, distributor)
- flow velocity (for open tanks, flow in channels)

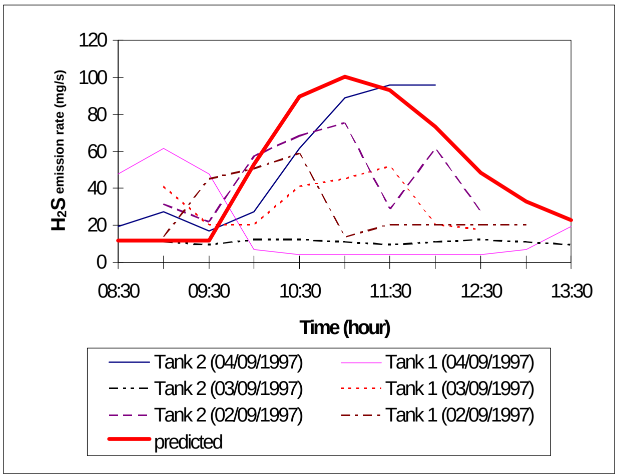
A number of other obviously significant factors, such as temperature and pH value do not need to be separately considered because they are accounted for by the value of the odour potential.
An example of the formulae produced by this means, for flow over a weir, is :

$$\mathbf{ER_{odour} = 7x10^{-4} \times OP \times Q_W \times h \times K_{pH}}$$

ER	-	odour emission rate, ou/s
OP	-	odour potential, ou/m^3
Q	-	flow rate of liquid over the weir
h	-	height of fall of water over the weir
K_{pH}	-	a second order pH correction factor, usually close to 1.

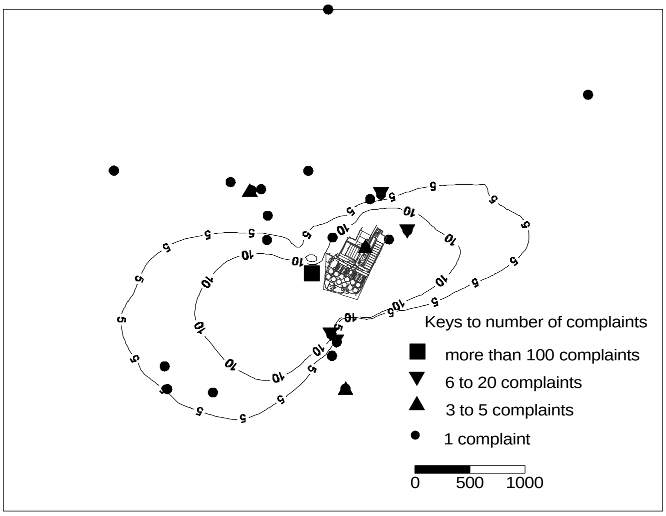


These formulae now exist for all of the common sewage treatment processes, and collectively are called the STOP (sewage treatment odour prediction) model. Related formulae also exist for predicting the emission rates of H_2S. The diagram to the left shows some measured and predicted odour emission rates for a weir. The test data was completely independent of the data used to develop the formula. Recently WRc has carried out a validation exercise of the STOP models at a large sewage treatment works. This involved both validating the predictions for individual processes, as well as that for the whole works. As an example, the STOP model was used to predict the H_2S emission rate from a sludge tank as it filled. Initially the sludge fell onto the exposed surface in the tank, necessitating the use of one STOP model. After a while the inlet became submerged under the rising sludge level, necessitating the use of a different model. The tank was vented at a constant rate by a fan. A spreadsheet model based on the STOP model predictions was used to simulate this tank, as shown in the diagram to the right. The model was based on general information as to how the tank operated, which may not have been followed every day, but a good match was obtained, particularly for Tank two on the 14/09.



The estimated odour emission rate for the whole works was validated against complaints. This was done by selecting a quality standard proposed elsewhere and believed to correlate with complaints. The standard selected was an odour strength less than 5 ou/m^3 for more than 98% of hours. An atmospheric dispersion model was used together with one year's met office data from a nearby airport to predict the footprint which did not meet the standard and this was compared against the positions of recorded complaints. In fact a number of odour abatement measures had been put into place over the previous 12 months, while the complaints were recorded covered an earlier period so it was likely that the estimated complaints footprint might be somewhat smaller than that logged. The size of the predicted complaints footprint (diagram, next page) is enough to cover all but two single complaints, though because of prevailing wind conditions it is predicted to be highly asymmetric. Given that the met. office data comes from a site several miles away it is not reasonable to expect the finer detail of the shape of the footprint to match this site.

Using WRc's database of odour potential values, this procedure has already been used on several occasions to predict odour impact for proposed greenfield sites for environmental statements and associated planning applications.



Odour Abatement. Inspection of the STOP formulae immediately points to two options for reducing odour emission rates

1. reduce the odour potential
2. reduce the odour transfer capability of the process

Odour potentials can be reduced by not allowing the development of anaerobic conditions responsible for odours. This can be done by maintaining levels of dissolved oxygen, if necessary by adding pure oxygen, or adding alternative sources of oxygen, such as nitrate. An increase in odour potential can be avoided by not adding highly odorous liquors - sludge liquors should be added directly to secondary treatment where they will oxidise, rather than being allowed to stand in primary tanks. Odours already formed can be oxidised. This generally requires stronger oxidising agents such as chlorine, ozone or hydrogen peroxide. Metal salts, in particular iron, will fix sulphide, preventing its volatilisation.

Transfer capabilities can be reduced by reducing turbulence by e.g. reducing free fall over weirs and avoiding dropping sludges and other highly odorous liquors onto free liquid surfaces.

As well as these methods for reducing odour emission rates, any process can be enclosed with treatment of the vented air. Standard methods of treatment include wet chemical scrubbing, adsorption onto activated carbon or by dry chemical absorbents, and biological oxidation in e.g. an odour biofilter. Thermal oxidation and catalytic destruction are rarely used in the water industry, though ducting odour into existing boilers, dryers and CHP plant should be considered more often. This is however common practice with sludge incinerators. One method used more commonly overseas and receiving renewed attention in the UK is to duct odorous air into the air intakes of secondary treatment plant where it will receive significant levels of odour reduction. This may not work if the secondary treatment plant is too highly loaded. Indeed very highly loaded plant can be significant sources of odour in their own right.

Current Work.

WRc is currently starting investigations into the rates at which odours develop under a range of conditions, including:

- anaerobic sewers, where the sewer walls will play a significant role
- primary tanks, where wall effects will be much less
- sewage overlying sludge, to represent primary tanks with a retained sludge blanket
- liquid sludges

At the same time the abilities of chemicals will be examined to either prevent or destroy odours.

The problem of odours in gravity sewers will also be investigated. Are they related to septicity developing in pockets of sediment or in slimes or can the smell of fresh sewage be sufficient to cause problems in certain circumstances?

WRc also intends to take another look at anaerobic digesters. The odour strength of digester gas has been observed to vary from typical values of under 1 million up to 100 million ou/m^3. Odours from secondary digesters are also associated with these very highly odorous digester gases. The variation could be due to the completeness of the digestion process but the high values have been observed where there are significant industrial discharges.

DISCUSSION

Question

No Questions on this paper