Matching odour treatment processes to odour sources

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Abstract Severn Trent Water Ltd. has reviewed the performance of its existing odour control technology and conducted trials with new technology. Processes were then selected for a costing exercise for air flow rates and odour concentrations typically found at sewage treatment works. The most cost effective processes for various applications are outlined.

Keywords Catalytic carbon; hydrogen sulphide; odour; biofilters; Peacemaker; iron filters

Introduction

Severn Trent Water Ltd operates over 1,000 sewage treatment works within the river basins of the Severn and Trent rivers, in the English Midlands. Around 5% of these sites receive odour complaints and pressure is increasing to reduce odours and prevent nuisance to neighbours. Experience has shown that abatement measures must deliver significant improvement. To install inadequate odour abatement equipment not only wastes money, but also causes public relations problems. If promises are not kept, customers lose confidence in the Company and demand higher standards.

There is a baffling array of odour abatement technology available, with many claiming to be the universal panacea. Some processes have developed a bad name, due to incorrect application or under specification, while others appear to be “flavour of the month” and are installed for every application with no thought to their suitability for that application.

Odour control is often one small part of a much larger construction project and, generally, the main contractor has little or no expertise in odour abatement. In these circumstances, he will be likely to select the cheapest quote for odour control, to keep costs low and win the contract. The user is then left with undersized or inappropriate equipment. To avoid these problems Severn Trent Water Ltd has been reviewing the performance of its installed odour control equipment and conducting trials with promising new technology.

Review of technology in Severn Trent

The first step was to look at the odour treatment units within Severn Trent and ask operators for their views on the unit and for any available cost or performance testing data. The results of the survey are summarised in Figure 1.

Of the biofilters not providing satisfactory performance, two were installed on raw sludge centrifuges and the third was grossly overloaded. The main problems with the biological systems were assessed to be inappropriate use of the technology. The problem plants received either highly variable feed concentrations or concentrations outside the operating range of biological systems. A further issue was the level of operator input required by bioscrubbers.

Three of the carbon installations were passive vents on tanker import facilities, while the fourth was a forced ventilation, tray system on raw sludge holding tanks. Carbon is not economic at hydrogen sulphide (H₂S) concentrations above 10 ppm – conditions frequently encountered at sewage treatment works. The problems stem from the high humidity of the air to be treated and the small size of the hydrogen sulphide molecule. Two sites reported problems with early exhaustion of potassium permanganate media on raw sludge holding tanks.
Severn Trent operates one chemical scrubbing plant on the raw sludge route at Strongford STW in Stoke on Trent. The scrubber is a single stage unit using sodium hypochlorite to oxidise odorous compounds. The operators are happy with its performance, although the operating costs are high.

Ten sites reported using sprays, none of which eliminated complaints completely. Counteractant sprays have been tested by the Water Research Council in the UK and found to be of similar effectiveness to water (James, 1993).

Little or no performance data existed to confirm the subjective assessment of installed odour control equipment. Cost data was more readily available, but in some cases it was not possible to extract accurate odour control costs with any confidence from total costs for much larger schemes.

Other available technology
A review of other available technology was conducted by a combination of literature searches, participation in a WRc project (James, 1994) and contacts with odour control specialists in other UK Water Companies. From these studies, it was determined that technology based on ultra violet lamps and ozone gave insufficient odour removal for the majority of applications. The revenue costs associated with the use of zeolite and ethysorb rendered these processes uneconomic. James (1994) costed four odour control scenarios with air flow rates of 1,000 and 5,000 m$^3$/h, both at 5 and 20 ppm H$_2$S, which showed chemical scrubbers to have twice the lifetime costs of biofilters.

Other processes looked worthy of further investigation: catalytic carbon, dry chemical scrubbers (Peacemakers), catalytic iron filters (CIFs) and alternative biofilter media. These processes are described below.

Northumbrian Water Ltd had interesting results from a trial of a new catalytic carbon, Centaur HSV, which was developed specifically for odour removal at sewage treatment works. It has 20 to 100 times more active sites than other carbons, increasing the loading capacity for H$_2$S from 1% to 15% weight for weight. At the catalytic sites H$_2$S and methyl mercaptans are oxidised to water soluble products. Ammonia and amines react with the resultant sulphuric acid to form water soluble ammonium sulphate. These oxidation products can be removed by washing with water, but other volatile compounds are not as readily removed. Therefore, these accumulate and the adsorption capacity for H$_2$S will decline with each regeneration cycle. The carbon may be water washed five to seven times, depending on the organics load, before the carbon needs to be replaced. Carbon does show good odour removal, it is the bed life and revenue costs which make it unsuitable for many sewage treatment applications. To prove the potential cost benefits of catalytic carbon, a trial unit treating 4,000 m$^3$/h was installed on sludge holding tanks at Derby STW.
Anglian Water (Naylor, 1998) and Dwyr Cymru (Houseman, 1998) have demonstrated excellent \( \text{H}_2\text{S} \) and mercaptans removal from Peacemakers. The modular units have two stages, the first stage consists of alumina pellets impregnated with stabilised chlorine dioxide which oxidise hydrogen sulphide, mercaptans and other odorous compounds. Chlorine dioxide is a powerful oxidising agent, four times stronger than potassium permanganate and two and a half times stronger than chlorine. Unlike chlorine and hypochlorite it does not react with ammonia and is not a chlorinating agent. The second polishing stage is impregnated with a patented countervaillant which removes ammonia and other compounds not oxidised by chlorine dioxide. Although there is an abundance of \( \text{H}_2\text{S} \) and mercaptan data available from spot measurements of Peacemakers, there is no published data available on total odour removal – as measured by olfactometry. Published papers contain no information on bedlife, although the manufacturers offer a five year guarantee. It was these aspects on which Severn Trent Water wanted more information. A pilot unit was installed at Finham STW, Coventry, on sludge holding tanks where carbon had exhausted within weeks. Due to limitations of space the test plant contained only the first treatment stage.

Boon (1998) and Houseman (1998) have presented papers on the use of catalytic iron filters to remove \( \text{H}_2\text{S} \) and mercaptans. Catalytic iron filters (CIFs) oxidise hydrogen sulphide to sulphur by reaction with iron oxide in the presence of atmospheric oxygen in two stages. Iron sulphide is formed as an intermediate before immediate oxidation back to iron oxide and elemental sulphur is deposited. The media is rusty iron mass transfer packing plus some inert media to support the iron as itrusts away. With hydrogen sulphide removals between 33 and 79% and mercaptan removal between 57 and 80%, CIFs provide a useful roughing stage to extend the media life of chemical processes, or reduce \( \text{H}_2\text{S} \) to levels suitable for biological treatment. CIFs and Peacemakers have been installed on a temporary sludge installation at Derby STW.

The use of calcified seaweed appears to overcome some of the performance problems associated with biological systems. Biofilters operated by Thames Water have been shown to perform well with highly variable feed concentrations (Berney, 1996). Calcified seaweed meets the criteria required for a successful biofilter media. It has a high specific surface area, good voidage and will support bacterial growth. Its physical and chemical properties provide certain advantages over the more traditional peat and heather biofilters. It does not compact when wet or shrink on drying, so maintaining a more even air flow through the bed. The media contains calcium carbonate, which neutralises acids and maintains a more regular \( \text{pH} \) within the bed. These properties are shared by mussel shells. A calcified seaweed bioscrubber was installed on sludge holding tanks at Stratford STW. An improvement in odours was perceived by customers, but complaints did not stop completely, due to other odour sources on site.

Performance testing

Performance data were required for existing odour control equipment operated by Severn Trent Water and those processes identified above as worthy of further investigation. Assessment of total odour removal by olfactometry was required, as well as hydrogen sulphide and mercaptans removal. All olfactometry was to the draft European standard CEN/TC264 ‘odours’. Hydrogen sulphide and mercaptans removal was measured using Drager tubes. Recent acquisition of a transportable “sweet and sour” hydrogen sulphide monitor has greatly improved the quality of hydrogen sulphide performance data.

Bioscrubbers were tested for \( \text{H}_2\text{S} \) and total odour removal. Where possible, two olfactometric tests were performed on each bioscrubber, one under ‘normal’ operating conditions and one under “stressed” conditions, i.e. when a tanker was unloading or primary sludge tanks were being desludged. The inlet odour concentrations ranged from 2,256 to
967,552 ouE/m³ while the outlets ranged from 1,375 to 371,038 ouE/m³. The percentage removals are given in Figure 2. All bioscrubbers treat odours from raw sludge tanks and tanker imports, except Site A (belt thickener) and the second scrubber at Site F (press plant). The bioscrubber at Site E was retested, due to the poor results obtained in the first test.

Figure 3 shows how the bioscrubber at Site C responds to changes in inlet hydrogen sulphide concentration. The outlet hydrogen sulphide head was scaled to 5 ppm, accounting for the flattened first peak. Data was logged at one minute intervals.

Hydrogen sulphide monitoring of a biofilter at Retford sewage treatment works, showed that imported sludge produced a peak feed concentration of 100 ppm, causing breakthrough of 1 ppm in the outlet. However, this performance was sufficient to stop odour complaints and was reported as operating satisfactorily.

Centaur HSV successfully removed H₂S levels over 600 ppm, but frequent regeneration would render the process uneconomic for such high concentrations. Operational changes on site, reduced the inlet H₂S to more reasonable levels, around 10 ppm.

The Peacemaker trial quickly confirmed excellent H₂S and mercaptan removal, H₂S peaks of 122 ppm were reduced to zero. Since the media lasted longer than carbon, Peacemakers were installed at a number of sites where biofilters were unsuitable, i.e. where space was limited or the odour was intermittent or had highly variable feed concentrations.

The results of the performance tests on the trial units and existing units are summarised in Tables 1 and 2. The olfactometric results for the biofilters are strongly influenced by the

<table>
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<th>Process</th>
<th>Number of units</th>
<th>Average inlet (ppm)</th>
<th>Maximum inlet (ppm)</th>
<th>Average outlet (ppm)</th>
<th>Maximum outlet (ppm)</th>
<th>Average removal (%)</th>
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<td>1</td>
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<th>Process</th>
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<th>Average outlet (ouE/m³)</th>
<th>Maximum outlet (ouE/m³)</th>
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<td>&gt;1,160,000</td>
<td>6,898</td>
<td>9,413</td>
<td>98</td>
</tr>
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<td>609</td>
<td>2,866</td>
<td>97</td>
</tr>
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<td>1,264,514</td>
<td>5,031,629</td>
<td>3,525</td>
<td>10,814</td>
<td>99</td>
</tr>
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</table>
results from the calcified seaweed biofilter, which was recorded as reducing over 5,000,000 ou/m³ to 10,814 ou/m³. Average odour removal for the other biofilters was 84%. Due to operational problems, it has not been possible to obtain performance data for the CIFs.

Costs
The catalytic carbon trialled at Derby was water washed seven times and lasted two years. Replacement costs for impregnated carbon have been estimated at £27,000, compared with £7,000 for one delivery of Centaur HSV.

The costs of catalytic carbon and Peacemakers were compared with the costs of calcified seaweed and mussel shell biofilters. The costing scenarios given in Table 3 were chosen as representative of the applications found at sewage treatment works.

Due to the lack of comparable, real cost data available, manufacturers supplied budget costs. Capital and whole life costs for the five scenarios are presented in Figures 4 and 5. Centaur HSV is clearly the cheapest option for the high flow rate, low odour concentration applications. For the other scenarios, the difference in cost is too small to separate the cheapest solution with any degree of confidence.

Discussion
Biological treatment has been shown to be unsuitable for high H₂S concentrations and highly variable loads. Oxidation of hydrogen sulphide by the bacteria produces sulphuric acid, lowering the pH of the biofilter media or bioscrubber recirculation liquor. As the pH drops, bacteria removing odours other than H₂S are adversely affected and removal efficiency of non-H₂S odours drops off (James, 1994). pH is controlled by adjusting the irrigation rate on biofilters or the bleed rate on a bioscrubber.

Biofilters seem to be able to handle concentration changes better than bioscrubbers. Low pH of the bioscrubber recirculation liquor reduces the mass transfer rate of hydrogen sulphide into the liquid phase. As the pH drops, longer retention times are required and
breakthrough occurs. The bioscrubber at site C received H$_2$S concentrations up to 600 ppm and bicarbonate dosing was required to maintain the pH. It was felt that bioscrubbers required a higher degree of manual control than is available at a sewage treatment works.

The Derby trials showed that catalytic carbon can be used cost effectively in raw sludge applications, but it is not suitable for every application. High organics loads reduce the carbon life and adversely affect the economics. High concentration scenarios, requiring frequent washing present a performance risk as units are taken out of service for up to three days during the wash cycle. Annual water regeneration can be performed during the winter to minimise risk of odour complaints and design should be based on regeneration frequencies no shorter than twelve months.

Peacemakers have been proven to be suitable for a wide range of applications. Their small footprint and ability to deal with hydrogen sulphide peaks makes them ideal for applications such as primary tank desludging wells and tanker import facilities. Correct performance specification is important. One unit tested on a sewage pumping station was installed without a performance specification. It removes 99.4% H$_2$S, but only 37% of total odour. Where total odour removal of 95% has been specified, the units removed 99% of the odours.

It is too soon to confirm whether the media bedlife, used by the manufacturer, is realistic. Severn Trent has only been using Peacemakers for 18 months. Biofilters have a good track record and are the “environmentally friendly” option. Their operating range could be increased above 50 ppm, by the use of CIFs to lower H$_2$S concentrations to acceptable levels. The decision to use Peacemakers instead of a CIF followed by a biofilter will eventually be down to economics.

Conclusions
Catalytic carbon is the most cost effective treatment, of those reviewed, for high volumes of low concentration odours, but is not suitable for high ratios of organic to sulphide odours. Peacemakers provide an effective treatment method where biofilters are unsuitable, i.e. where space is limited, or odours are intermittent or of highly variable concentration. Lifetime costs will be confirmed with time. For relatively steady H$_2$S concentrations below 50 ppm, biofilters provide a well proven treatment method. For concentrations above 50 ppm H$_2$S, the options are Peacemaker, CIF plus Peacemaker or CIF plus biofilter with the decision based on lifetime costs.

References