Modelling to solve odour problems

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Abstract The use of dispersion modelling is a powerful tool to establish levels of treatment required to remove odour complaints. Odour is an extremely sensitive issue and is key to the public perception of wastewater environmental protection. This paper describes a case study of the successful resolution of long-standing odour problems at the East Worthing Wastewater Treatment Works (WTW), on the South Coast of England, utilising modelling and appropriate treatment technologies.

A number of odour surveys have been conducted on the site to identify the major sources on the works, which were found to be the sludge press house and the primary settlement tanks, situated only 10 metres from the nearest properties. As a result attempts to resolve the odour problem have been made including the covering of identified sources, treating extract using activated carbon filters and installing perfume sprays.

During the site development all sources were contained and ventilated to a 60,000 m^3/hr Jones & Attwood ODORGARD^{TM} unit. Its requirement was to ensure that no receptor was exposed to a concentration in excess of 4 ou_Em^3 (Odour units), in accordance with the odour planning condition.

Dispersal modelling was performed to determine the maximum permissible outlet concentration. The results of the modelling exercise established that emissions from the odour control plant should not exceed 675 ou_Em^3 to ensure that the receptor standard was attained. An optimisation programme was conducted to ensure that the unit was providing the optimum level of treatment prior to taking the olfactometry samples. Following the plant's optimisation the results of the olfactometry analysis confirmed that the discharge levels were below the required 670 ou_Em^3. Since completion of the sludge treatment centre scheme there have been no registered odour complaints directed at the East Worthing WTW, and the local air quality has been greatly improved for the residents surrounding the works.

Keywords Dispersion modelling; hydrogen sulphide; ODORGARD^{TM}; odour; optimisation

Introduction

The East Worthing Wastewater Treatment Works (WTW) is situated in the South East area of Worthing, between the Meadow Road Industrial Estate, Seamill Way residential area and the Brooklands Park strategic gap, and treats a population equivalent of 138,000. The site has had some degree of wastewater treatment for approximately 100 years. As the town of Worthing grew so did the requirement for wastewater treatment at the East Worthing site and eventually the urban development came into close contact with the town's municipal wastewater treatment. During the 1930s the urban expansion of the town led to the development of the residential areas immediately surrounding the works.

As the town grew so did its wastewater treatment requirements. The catchment expanded and consequently retention times in the sewer network increased. The problem of treatment sizing was also exacerbated because of the high summer populations as a result of the tourist trade within the area. The combination of long retention times in the sewerage network, combined with treatment capacity design to deal with peak summer flows meant that there were ideal conditions for the formation and release of odorous compounds.

Unsurprisingly the works began to suffer from odour related complaints, a fact that has been exacerbated by the extremely close proximity of residential properties to the process units on the works. The extent of the proximity issue can be seen in Figure 1.

Many attempts were made at addressing the odour problem at East Worthing, however these were initially piecemeal and without co-ordinated focus. One of the first areas to be addressed was the inlet wet well and screens. This area was enclosed within a building and

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Figure 1 Aerial photograph of East Worthing WTW, circa 1995

air was extracted through a dry chemical scrubber. The ventilation rate however was insufficient which resulted in significant humidity problems within the building. Although the exercise successfully reduced emissions from the inlet works, the works continued to create a nuisance from other sources.

Another major source that was targeted was the release from the primary tanks and storm tanks (shown in Figure 1). A number of perfume spray formulations were trialled over a number of years, however if anything thing these sprays appeared to make the situation worse and were discontinued.

In 1993 Southern Water began a £42 million programme of works to improve wastewater treatment standards and to meet European environmental quality standards for the East Worthing works. Southern Water took this investment opportunity to finally deal with the odour problems of the site as an integral aspect of the project. A programme of work was conducted to identify the sources, recommend areas requiring treatment and specification of appropriate containment and treatment systems.

Baseline investigations

To enable Southern Water to fully appreciate the extent of the problems at the East Worthing works it was necessary to perform baseline odour assessments. Southern Science Ltd was commissioned to perform baseline hydrogen sulphide surveys. These surveys involved the measurement of hydrogen sulphide concentrations, in the range of 1 ppb to 50000 ppb, using a Jerome 631-X. The first of these surveys was conducted in May 1995 (Southern Science Ltd, 1995). This first survey identified the following areas as having particular problems:

- De-sludge wells
- Press house
- Inlet baffles to the primary tanks
- Sludge holding tanks
- Primary sludge transfer wet wells

Following the first Southern Science report, covers were placed on the wet well areas and the odour control system in the press house was refurbished. To determine the effectiveness of these measures the survey was repeated in February 1996 (Southern Science Ltd, 1996). The results of this second survey confirmed a reduction in hydrogen sulphide concentrations, however it was possible that this was a result of the survey being conducted in winter. However the primary tanks and de-sludge wells were still releasing concentrations above 40 ppm, and with their proximity to the residential area of Seamill Way the odour situation was still unacceptable.

Odour control scope for the new development

The development of the East Worthing WTW required the installation of a new sludge cake handling facility, and new liquor treatment plant, new sludge centrifuges, new holding and thickening tanks and refurbishment of the sites digesters. This new development required planning permission, and as such Southern Water had to demonstrate that sufficient proposals were in place to ensure the odour situation would not become worse. Southern Water decided that, over and above the requirements to control emissions from the new development, the scheme would address all odour sources previously on the site.

The odour control strategy required all odour sources to be physically contained, and foul air extracted and treated in a single odour abatement plant. This process was relatively simple for the new process building being developed.

The sludge cake reception building was designed to accept cake from other sites, and to blend this with indigenous sludge prior to transfer to the sludge holding tanks. All of these facilities were contained within a single building. The ventilation system for the building was essentially divided into two sections, the import bay and the blending area. The import bay had to be designed to ensure that odour would not escape during the deliveries of cake to the site. To ensure this bay was equipped with an air lock, within which lorries are required to wait until a volume of air has been extracted. To protect personnel, the lorries exhaust was extracted from the bay using a flexible hose connected directly onto the exhaust pipe. This prevented carbon monoxide and other combustion products from being released into the bay during the unloading process. In addition extraction points were fitted at high and low levels in the bay. A similar arrangement of ventilation system was fitted into the blend plant area. The net result was that the building contained any odours released, and the extraction system removed them to the treatment plant.

The other new areas of the plant were more straightforward to odour control. The sludge holding tanks and the liquor treatment plant were covered and extracted, and the sludge centrifuge building contained both local ventilation for the centrifuges and general ventilation for the building itself.

The question still remained on what to do with the existing sources. The press house was easy; it was to be demolished as it was being replaced with centrifuges. The decision was made to cover all channels and the primary settlement and storm tanks. The covering of the primary settlement and storm tank presented a particular problem with the two primary tanks being 45 m long and 15 m wide, and the two storm tanks being 58 m long and 15 m wide. A total of 68 GRP sections were fitted to cover the complete area, with each section being 15 m $\times$ 3 m. All flow channels and wet wells were also covered with GRP.

Although covers were placed over the primary tanks, installing automatic de-sludging reduced the loading from this area. The automatic de-sludge system enables the sludge blanket to be kept at optimum thickness and density. This helps prevent the formation of hydrogen sulphide within the sludge blanket.

The completed works can been seen in Figure 2.

The result of the containment exercise was that there was no area of flow that was

Figure 2 Aerial photograph of East Worthing WTW, circa 1998

exposed to the atmosphere. All sources had been contained, and all were extracted to a central odour abatement system.

Emission limits

Having determined the required level of containment and extraction from all the sources, the next step was to agree a level of treatment with the local authority to ensure planning permission was granted. Although planning in the England and Wales is determined by the Planning Authority, generally being the County Council, matters regarding potential air quality issues are generally deferred to the local Environmental Health Officer (EHO). Although the position is changing, in 1996 EHOs had little knowledge concerning odour issues and therefore commissioned consultancies to provide the expert advice required.

To assist Worthing Borough Council in understanding the technical issues concerning odour with the East Worthing development, AEA Technology were commissioned to perform an assessment of Southern Water's odour control proposals for the scheme (Worthing Borough Council have kindly permitted the use of this data within this paper). The AEA Technology report (AEA Technology, 1996) concluded that the Southern Water proposals appeared to address all the odour sources, and that the proposed containment should be effective as long as the ventilation system runs to its design parameters.

AEA Technology also provided Worthing Borough Council with a recommendation for the performance limit of the odour control system. The report (AEA Technology, 1996) stated:

"The ground level odour concentration should not exceed about 4 ou/m^3 as a result of the discharge from the entire plant operation. In this case the 4 ou/m^3 would need to be predicted using emissions data (determined in the discharge stack) and an up-to date dispersion model (e.g. UK ADMS2). The ground level concentration as described is what is added to the local environment as a result of the plant operation, normal background odours are excluded."

Following the acceptance of AEA Technology's report Worthing Borough Council granted the development planning permission. One of the conditions of the development was as follows:

"Unless agreed otherwise with the County Planning Authority the ground level odour concentrations, as a result of discharges from operations on the site following completion of the development hereby permitted, as determined at locations to be agreed by the County Planning Authority on and outside the site boundary shall not exceed 4 ou/m^3. . ."

It was subsequently agreed with Worthing Borough Council that a dispersion modelling exercise should be performed, and the maximum discharge concentration determined which would ensure no receptor was exposed to an odour unit concentration in excess of 4 ou/m^3.

Dispersion modelling

To maintain consistency with the planning work, AEA Technology were commissioned by Southern Water to perform a dispersion modelling exercise to determine the maximum emission concentration from the odour abatement plant which predicts no receptor would be exposed to a concentration in excess of 4 ou/m^3.

The model selected by AEA Technology was UK ADMS2. There are a number of dispersion modelling packages in use for odour assessments, however the most common fall into two categories:

- models that characterise the boundary layer using Pasquill-Gifford stability categories e.g. ISCST3
- models which characterise the boundary layer using the Monin-Obukhov length and the boundary layer height e.g. UK ADMS2.

One of the fundamental differences between the two systems is that Pasquill-Gifford model distribution is always Gaussian, however UK ADMS2 is Gaussian in stable and neutral conditions, but is non-Gaussian in convective conditions (CERC, 1995).

The AEA Technology report (AEA Technology, 1998) examined three basic scenarios; volumetric flows at 40,000m^3/hr, 50,000m^3/hr and 60,000m^3/hr. UK ADMS contains a number of modules to allow for more accurate approximation of the scenario being modelled. The first of these modules considered was terrain. The area surrounding the East Worthing site is relatively flat, as can be seen in Figure 1, consequently the complex terrain module of ADMS was not employed. In the initial set up the surface roughness was assumed to be 0.5 m, which is the recommended value for areas with areas of grassland and open suburbia.

Perhaps the most important module for these modelling exercises is building downwash. Buildings can create areas of low pressure within the downwind side of the structure that can entrain emission plumes (see Figure 3). This entrainment changes the shape of the plume and fundamentally effects its subsequent dispersion. Essentially two plumes are formed, a ground-level plume formed from the recirculating flow region in the entrained area of the building and an elevated plume from the non-entrained remainder (CERC, 1995). For the East Worthing model a total of ten structures were detailed, with two of the most significant structures being the council depot and the sites sludge dewatering building.

Although actual meteorological (Met) data is available for UK ADMS, AEA Technology created a derived Met data file that contained all the meteorological conditions likely to occur in the Worthing area.

With the modules set, the emission parameters for the odour abatement plant could be defined. The stack height was set at 20 m, with an exit diameter of 0.97 m. The three scenarios modelled of 40,000 m^3/hr, 50,000 m^3/hr and 60,000 m^3/hr provide respective efflux velocities of 15 m/s, 18.8 m/s and 22.5 m/s.

The model was then able to predict the maximum permissible release concentration, for each flow rate, which would ensure the planning condition of 4 ou/m^3 would not be exceeded. The results are presented below:

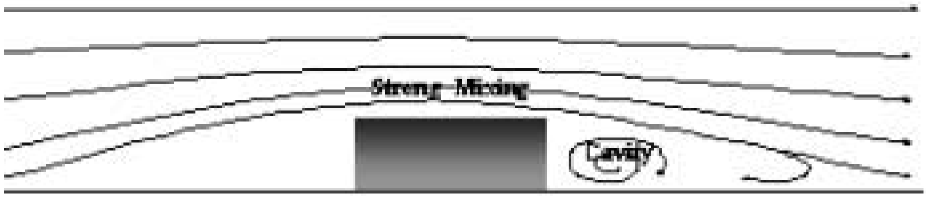

Figure 3 Simplified drawing of flow over a building

40,000 m^3/hr – Maximum permissible release concentration = 998 ou/m^3
50,000 m^3/hr – Maximum permissible release concentration = 837 ou/m^3
60,000 m^3/hr – Maximum permissible release concentration = 735 ou/m^3

Odour abatement plant

The subcontract for the odour abatement plant was awarded to Jones & Attwood who designed and installed an ODORGARD™ wet chemical scrubber (Figure 4). The system essentially is a single stage alkaline hypochlorite wet chemical scrubber with the addition of an ICI Katalco ODORGARD catalyst. The mass transfer, from the gas liquid phase, occurs within the scrubbing tower. In conventional wet chemical scrubbing systems this is where the oxidation of odorous compounds also occurs. The catalyst provides additional opportunity for increased oxidation through the decomposition of the hypochlorite ion, on the nickel oxide surface, forming a metal intermediate oxide and releasing a chloride ion (Higgins, 1998). The net result of the combined system is that the oxidation reaction rates are promoted, with the beneficial effect that there is a reduction in incomplete chlorination reactions that result in bleach odours being released from the stack.

One limitation of the ODORGARD™ system is that it works at a single pH and consequently the mass transfer chemistry will always be a compromise between the removal of acidic gases and the removal of basic gases. The original pH set point for the system was 9, which theoretically will ensure all hydrogen sulphide is present in the ionised form according to its dissociated equilibria (WRc, 1980), and 50% of the ammonia will be in the ionised form according to its dissociated equilibria (WRc, 1980). Any increase in pH will dramatically effect the dissociation of ammonia, and consequently the units' ability to remove it from the air stream. As a consequence of this limitation, an optimisation study

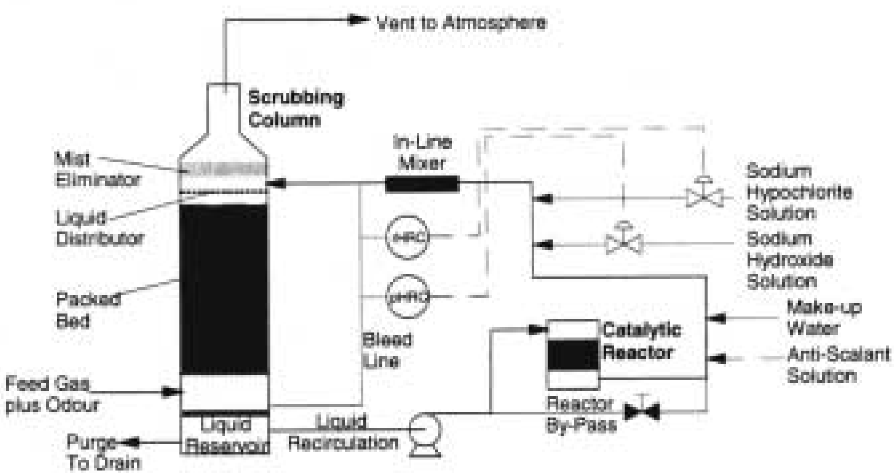

Figure 4 Simplified ODORGARD™ Process Flow Diagram (Higgins, 1998)

was undertaken to ensure the unit had the best chance of passing the olfactometry analysis required by the planning condition.

During the optimisation study the hydrogen sulphide emission concentrations were monitored in two ways, firstly using a fixed Zellweger SPM hydrogen sulphide monitor, and secondly using a Jerome 631-X gold film analyser connected to a data logger. The Zellweger was giving continuous low concentrations, in the range of 1 ppb to 4 ppb, however the first set of data from the Jerome gave concentrations in the range of 15 ppb to 40 ppb. The Zellweger was checked, as was the Jerome and no fault was identified with either instrument. The only difference between the two was that the Jerome also detects organic sulphur compounds such as methyl mercaptan and dimethyl disulphide. The obvious explanation was that the increase in levels monitored by the Jerome was as a contribution from organic sulphur compounds. This explanation was supported by the first set of logged data from the Jerome that identified spikes that coincided with the desludging of the primary tanks.

Having identified the presence of organo-sulphur compounds the system had to be optimised to remove them from the air stream. Mr Mark Higgins (Jones & Attwood) kindly assisted in this process by recommending the pH change required to remove these compounds. It was recommended that the pH needed to be increased, which would affect the systems ability to remove ammonia. Southern Water have only experienced ammonia problems on sites which dosed lime, which was not being done at East Worthing, consequently the decision was taken to raise the pH to 9.5.

The pH change appeared to eliminate the spikes from the de-sludging process, and therefore had achieved a significant degree of success. However the general level, of around 15 ppb, was still significantly higher than that recorded from the Zellweger. To attempt to address this the pH was further increased to 9.8. This again produced significant results, lowering the Jerome readings to below 10 ppb. These results can be seen in Figure 5.

The system had been fully optimised and consequently the olfactometry analysis of the plant emissions could take place.

Olfactometry

WRc were commissioned by Jones & Attwood to undertake olfactometric analysis of the East Worthing odour abatement system in accordance with the draft CEN standard TC264 (CEN TC264, 1997). The samples were collected on June 30th 1998, and analysed within 24 hours by AEA Technology. The three outlet concentrations gave a mean concentration from the system of 639 ou/m^3, at a flow rate of 60,000 m^3/hr.

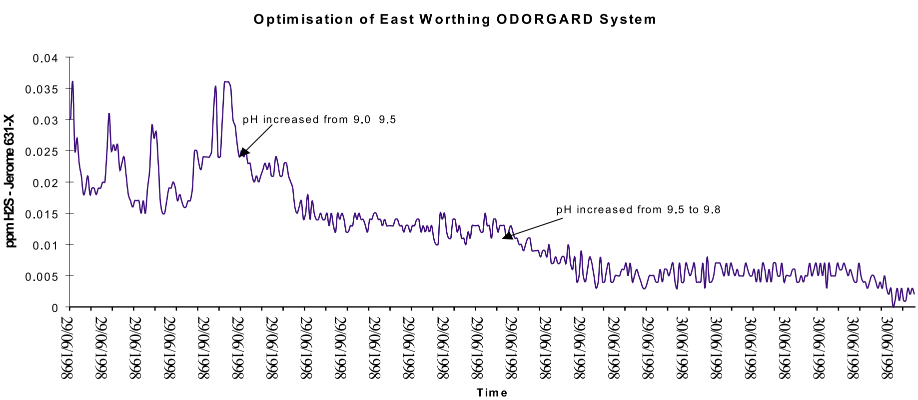

Figure 5 East Worthing Odour Abatement Optimisation

Conclusions

The dispersion modelling, conducted by AEA Technology, predicted that the required emission concentration to achieve 4 ou/m^3 was 735 ou/m^3, the results of the olfactometry gave an emission concentration of 639 ou/m^3, consequently the East Worthing odour abatement plant successfully discharged its odour related planning condition. More importantly however the East Worthing scheme successfully addressed a long-term odour problem to the point where, since completion, the works have not received a single odour complaint.

The successful solution to East Worthing's odour problems involved a combination of accurate scoping of the work required, good containment design and installation, appropriate specification of odour abatement plant and the installation and optimisation of the abatement plant.

Atmospheric dispersion modelling has played a pivotal role in the resolution of East Worthing's odour problems. Modelling has enabled the designers and engineers to know exactly the constraints they are under and the performance they are expected to achieve.

All Southern Water odour abatement plants require dispersion modelling under the contract. This is intended to ensure that following installation the odour problem is resolved cost effectively.

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