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Impact of variable emission rates on odour modelling at WwTW's

Stephenson, T., Callister, S., Harper, P.L.S.

Water Innovate Ltd

ABSTRACT

The use of dispersion modelling as a means of regulating the impact of odours from WwTW's on surrounding areas is increasing. Although dispersion modelling is an invaluable tool in assessing odour impacts, its accuracy depends primarily on the emission rates used in the model. Current practice is to use static emission rates, either from look-up tables, or site sampling, despite the known variability of emissions. If dispersion modelling is to provide the accuracy required of a regulatory tool, an assessment of the impact of variability of emissions on the results obtained needs to be undertaken.

This paper presents a case study of variable emission rate modelling using ODOURsim®, and the impact of variable emissions on dispersion modelling results. ODOURsim® is a novel odour emission modelling software package that has been developed for accurately predicting odours from sewage works by determining the rate of generation at source. A biological model derived from the well-known ASM_2 kinetic model is used to calculate the formation of H_2S in the liquid phase. The emission rates from the liquid to gas phase are calculated using a suite of process-specific mass-transfer models. The calculated variable emission rates can then be included in proprietary dispersion models as an hourly emission file. Methods and techniques used for the calibration and validation of the ODOURsim® emission rate model are described.

Inputs to the ODOURsim® emission model for the case study sites were standard wastewater quality measurements (TCOD, SCOD, pH, Temperature, Soluble Sulphide), allowing diurnal variation profiles to be simulated. The diurnal profile was used in combination with one years hourly flow data to produce the years' hourly influent file for the model. Emission rates obtained from the ODOURsim® model were used in the dispersion model to obtain contour plots for odour dispersion from the case site.

Graphical dispersion results of a diurnal simulation of a medium sized WwTW are presented. Dispersion model results, both instantaneous and yearly percentile contour plots, are compared for both variable and static emissions. Significant differences between the yearly percentile contour plots for variable and static emission rates have been observed at a medium sized WwTW.

Implications for design of odour control equipment with regards to data analysis of the simulation results for calculation of peak to mean ratios are discussed.

KEY WORDS

Odour, Odour Modelling, Emission Modelling, Hydrogen Sulphide.

INTRODUCTION

Development of land adjacent to WwTW's, increasing public awareness of environmental issues, and higher wastewater loads have all been factors in increasing pressure on water utilities to effectively manage odour emissions from WwTW's.

DEFRA has published the CoP relating to Odour Nuisance from WwTW's (Defra, 2006) which highlights methods by which an assessment of odour impact of the WwTW's can be made. These can include complaint frequency and location analysis, population surveys, site "sniff tests", ambient monitoring at receptors, and air dispersion modelling.

The use of dynamic olfactometry, for ambient monitoring is not recommended, as it suffers from poor reproducibility, especially at the lower concentration limits of "nuisance". Complaint frequency and location analysis can be a useful tool in examining the current issues at a WwTW, but affords no predictive capability. With the high cost of odour abatement options, both the utilities and regulators require a tool which will predict the effects of process and operational changes to the works on odour impact in order to determine the optimal cost-benefit solution.

The trend has been to use dispersion models to predict the odour concentrations from WwTW's. Current practice is to treat the emission rates as constant. The dispersion model will therefore only examine the impact of meteorological conditions on dispersion, and not on the formation and emission of odourants.

The resulting odour contour plots are often used in support of planning applications to demonstrate management of nuisance potential. Such outputs can also be used to inform decisions about selection of odour control technologies for new or existing works. However, an over-emphasis on dispersion modelling, where the variability of odour formation and emission is treated simplistically, could potentially give an inaccurate prediction.

ODOURsim® has been developed to fill this gap in current odour modelling techniques. It is based on the mechanistic modelling of the formation and mass transfer emission of H2S. (Gostello *et. al.*, 2001[a,b])

ODOURsim® allows informed design decisions to be made on the basis of predicted location, rate and timing of odour generation, emission and dispersion.

HISTORY

The case site is a medium sized WwTW in the East Anglian region. The site has a history of increasing complaint levels due to development to the West and North of the works. The works has three treatment streams, Old (1930's), New (1970's) trickling filters, and an AS plant (1990's). The inlet to the works takes flow from gravity sewers, but also has a long incoming rising main, resulting in septicity issues. The raised inlet structure conveys the crude sewage through screens to the detritors, is then combined with sludge liquor return flows, and cascades 2m to a mixing chamber before passing to the PST distribution system, and then through the downstream processes.

MODELLING METHOD

Wastewater sampling for TCOD, SCOD, soluble sulphide, pH, and temperature was carried out over a 48 hr period (2hrly composite samples), at the crude, settled, and effluents of each of the process streams.

Micrometeorological sampling (H_2S mapping using Jerome 631X H_2S analyser) was carried out over a 1 hour period on each of the wastewater sampling days at reference locations on the works.

An AERMOD model was constructed using the site map and the sources identified during the site visits. Emission rates were back-fitted using the AERMOD model and H_2S mapping results. This involved iteratively inputting emission rates for the upwind sources, running the AERMOD model to verify correlation with measured values, and proceeding to the downwind sources.

An 48hr input file was created from the diurnal flow and load pattern sampling.

The following wastewater state variable stoichiometries were applied:

Soluble Substrate SS = SCOD – $SCOD_{eff}$

Particulate Substrate X_S = 0.6(TCOD – SCOD)

Active heterotrophic biomass XB_W = 0.2(TCOD – SCOD)

An ODOURsim® model of the site was built using process sizing information, as-built drawings, and on-site measurement. The liquid-phase of the model was then calibrated to the measured wastewater characteristic trends over the first 24 hrs. The gas-phase of the model was

Table 1: Emission rates used in dispersion model scenarios

	Constant emission	Micromet		OdourSim		
Source		**Day1**	**Day2**	**Day1**	**Day2**	**Units**
Inlet Reception chamber	34.8	1.5	4.17	1.416	3.054	**ug/m^2/sec**
Inlet Screen Channel	4.17	1.5	4.17	1.560	3.371	**ug/m^2/sec**
Detritor	4.17	1.5	4.17	1.002	2.172	**ug/m^2/sec**
Inlet channel A	4.17	1.5	4.17	3.843	8.341	**ug/m^2/sec**
Recirc Chamber	173.7	1.5	1.5	1.051	1.052	**ug/m^2/sec**
Recirc channel	NA	1.5	1.5	2.935	2.934	**ug/m^2/sec**
Recirc drop	NA	5000	7000	4161	6390	**ug/sec**
Inlet channel B	NA	30	40	30.130	39.890	**ug/m^2/sec**
Inlet Mix chamber	173.7	5	5	3.003	3.948	**ug/m^2/sec**
Distribution weir PST1-3	NA	173.7	260.55	158.908	287.562	**ug/m^2/sec**
Distribution weir PST 4-5	NA	115.8	173.7	105.939	191.708	**ug/m^2/sec**
Settled collection chamber	NA	50	100	39.197	105.022	**ug/m^2/sec**
PST1-3	1.39	0.1	1	0.133	1.025	**ug/m^2/sec**
PSTweir 1-3	NA	20	60	21.88	58.9	**ug/sec**
PST4-5	1.39	0.1	1	0.133	1.025	**ug/m^2/sec**
PST weir 4-5	NA	20	60	21.88	58.9	**ug/sec**
A works Filters	5.876	0.25	1.5	0.261	1.765	**ug/m^2/sec**
A works Dortmunds	0.695	0	0	0.001	0.019	**ug/m^2/sec**
A works HT's	0.695	0	0	0.000	0.000	**ug/m^2/sec**
B works filters	0.525	0.5	5	0.479	4.937	**ug/m^2/sec**
B works HT's	0.695	0	0	0.000	0.000	**ug/m^2/sec**
C works AS lanes	2.78	0	0	0.001	0.001	**ug/m^2/sec**
C works FST	0.695	0	0	0.000	0.000	**ug/m^2/sec**

calibrated to the emission rates derived from the first day of the micrometeorological study.

The model was then run over the full 48hr period and a comparison of the emission rates from the identified sources with the second micrometeorological study carried out. This ensured validation of the model over the second 24hr period.

The calculated emission rates from the calibrated and validated 48hr emission model run were used as inputs into the AERMOD model, and 48 one hour runs were performed to yield the emission contour plots for each hour of the 48hr period.

An hourly wastewater input file was generated by dividing the diurnal hourly load by the hourly wastewater influent flow for the year.

The calibrated emission model was then run for the annual period using the new wastewater input file

The results from the emission model were then inputted into the AERMOD model with the corresponding meteorological data to yield the 98%ile contour plot for the year.

The AERMOD model was re-run using constant emission rates derived from values obtained from a previous study using the UKWIR emissions look-up-table [iv] to yield the 98%ile contour plot for the year.

Table 1 details the emission rates used in the air dispersion modelling scenarios.

RESULTS

Figures 1, 2, and 3 compare the H_2S contour maps for the micrometeorological study, ODOURsim® calibration, and constant emissions for the first calibration day.

As one would expect, a good fit was obtained between the micrometeorologically determined emission rates and the ODOURsim® model for the calibration day. This indicates that the AERMOD model adequately describes the sources and emissions correctly, and that the emisssion model can be successfully calibrated to the observed emission rates.

Figures 4, 5, and 6 compare the contour maps for the micrometeorological study, ODOURsim® calibration, and constant emissions for the validation day.

The comparison between the micrometeorological observations and the constant emission rate contour plots indicates that the constant emission rates are not representative of the instant hourly concentrations observed on site. This has ramifications in terms of predicting when and where complaints are likely to occur, and negates the use of receptor threshold exceedance testing as a means of determining FIDOL (Frequency, Intensity, Duration, Offensiveness, and Location) as specified in the CoP, (Defra, 2006).

The dispersion contour plots from the diurnal emissions of the WwTW are shown in Figure 7. This demonstrates the impacts of the variability of both the emissions and the meteorological parameters on the spread of odour from the site. This information is particularly useful in determining effects of sludge liquor (high sulphide) return flows and loads on emissions from downstream processes.

Figures 8 and 9 indicate annual frequency analysis plots for the "B" works trickling filters and the Drop Structure. The Trickling filter distribution follows a lognormal distribution, whereas the drop structure emission frequency distribution has a much more pronounced tail indicating a larger frequency of higher emission rates.

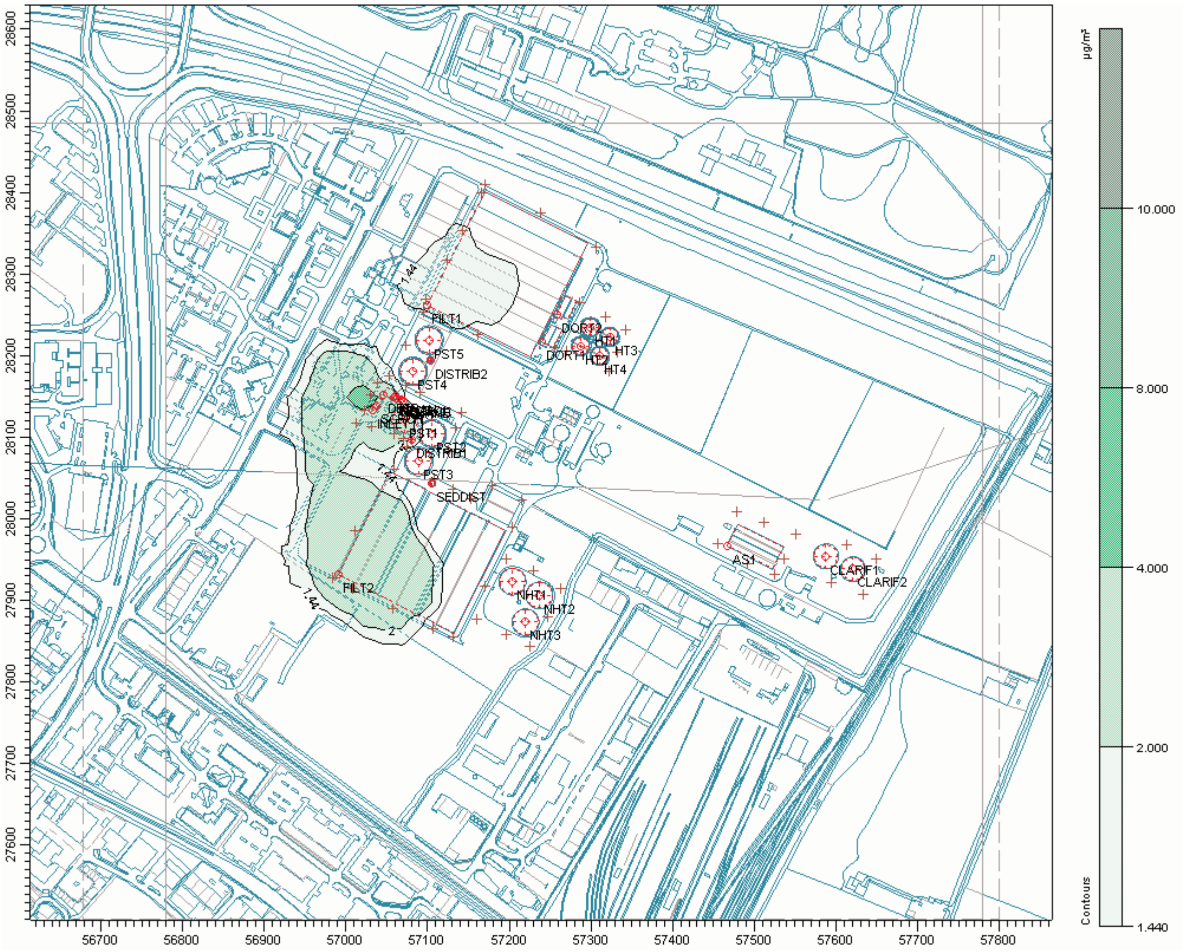

Figure 1: Contour Plot Fitted Micrometeorological Survey Day 1

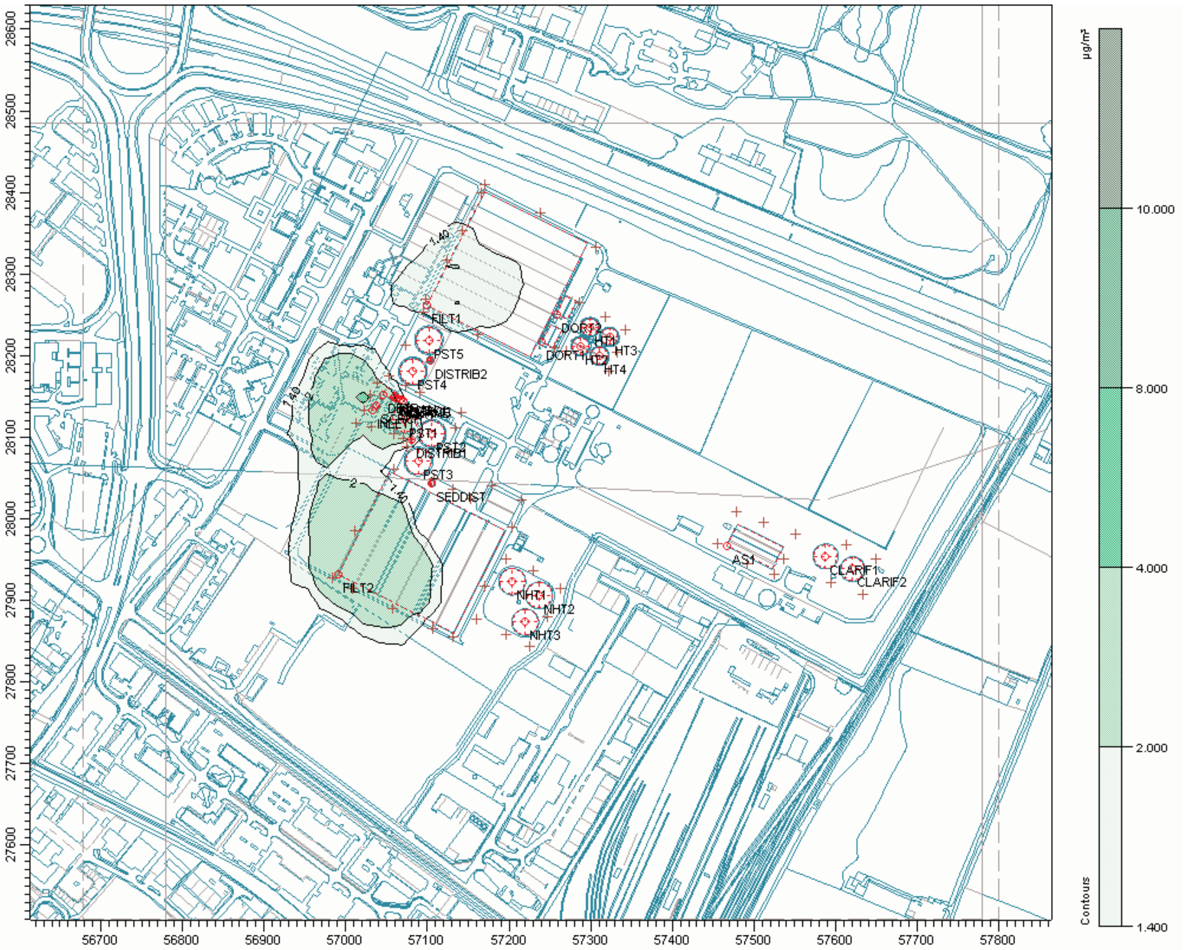

Figure 2 Contour Plot ODOURsim® Calibrated data Day 1

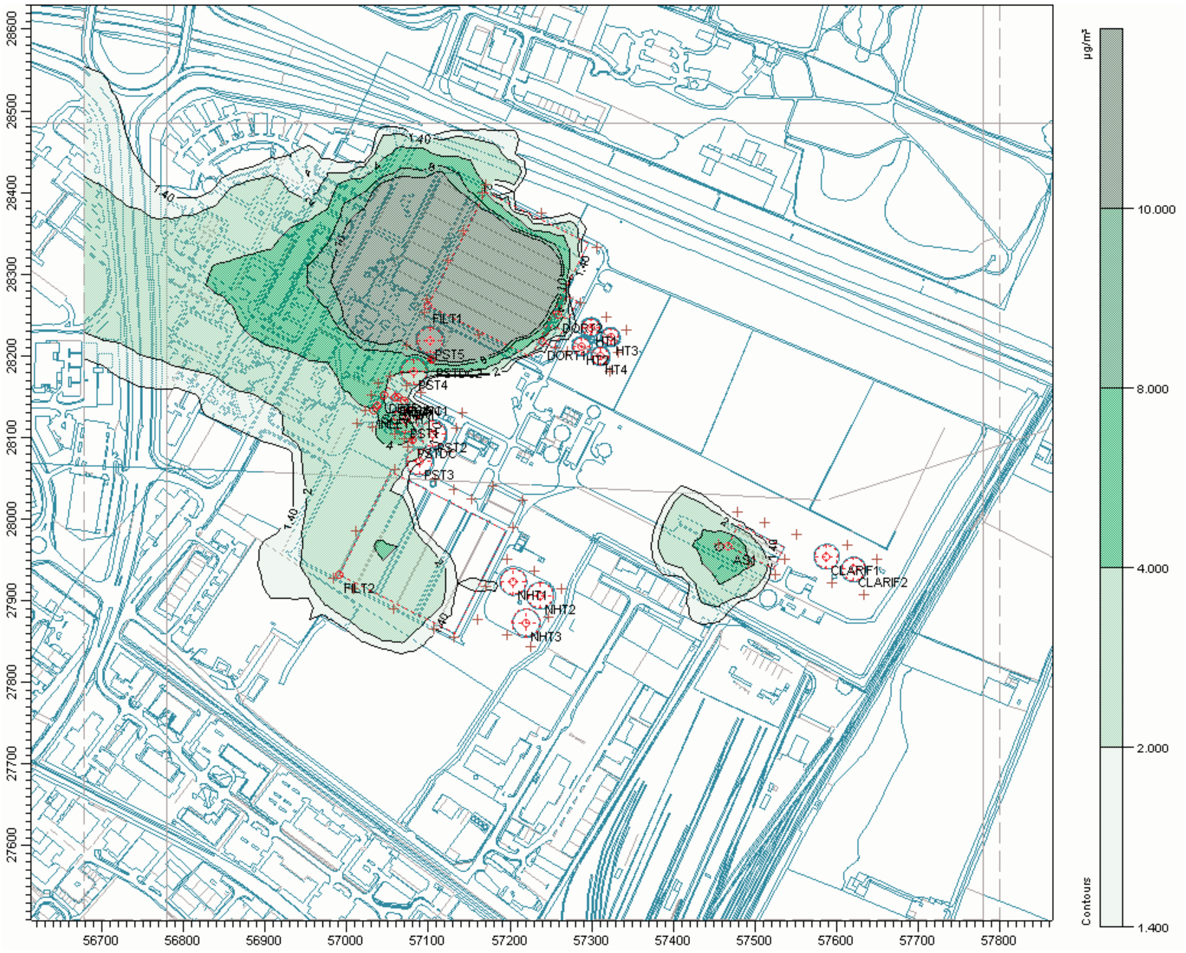

Figure 3: Contour Plot LUT “typical” emissions Day 1

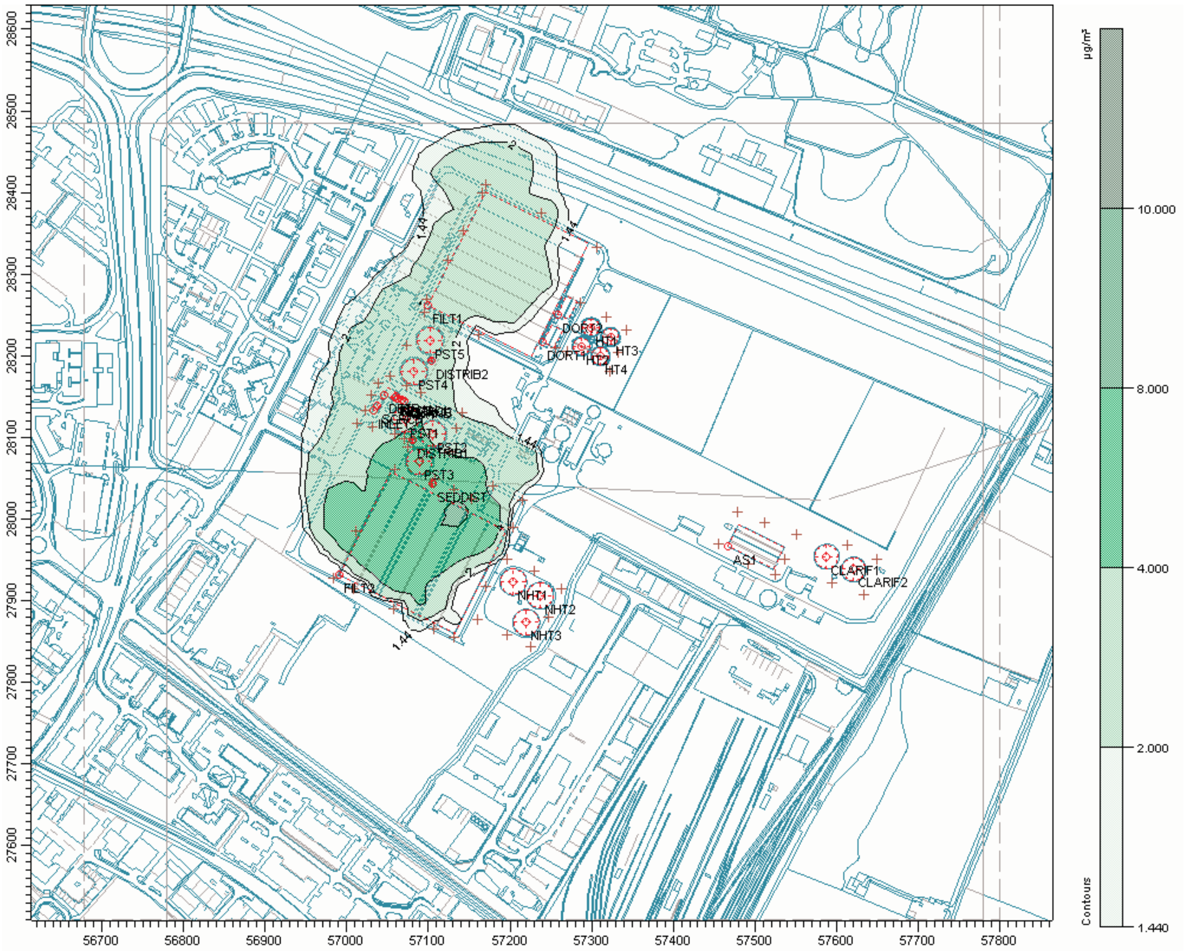

Figure 4: **Contour Plot Fitted Micrometeorological Survey Day 2**

Figure 5: **Contour Plot ODOURsim® data Day 2**

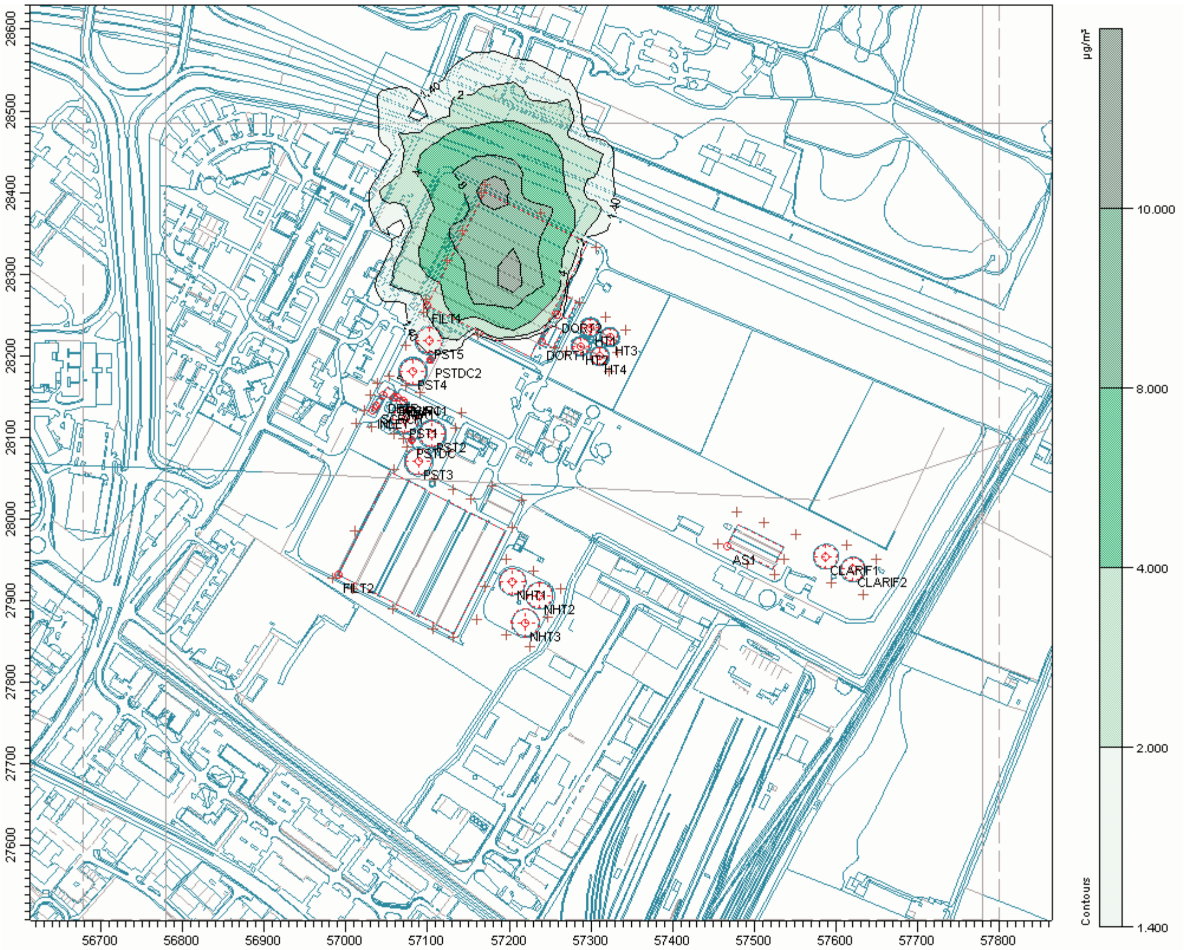

Figure 6: Contour Plot LUT “typical” emissions Day 2

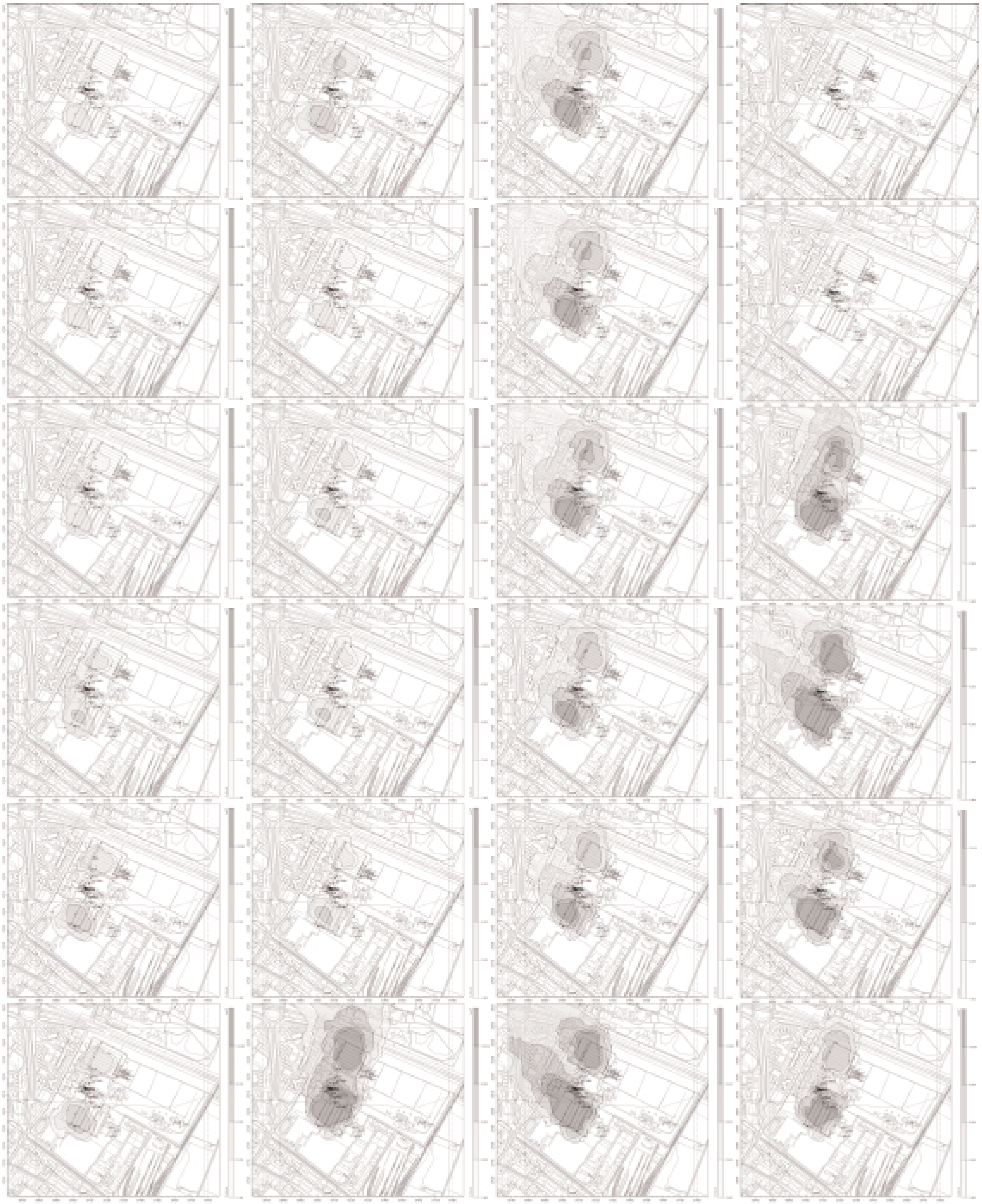

Figure 7: Diurnal variation in odour emission and dispersion for Day 1 (Hours 1-24 in vertical sequence, calm hours 20-21)

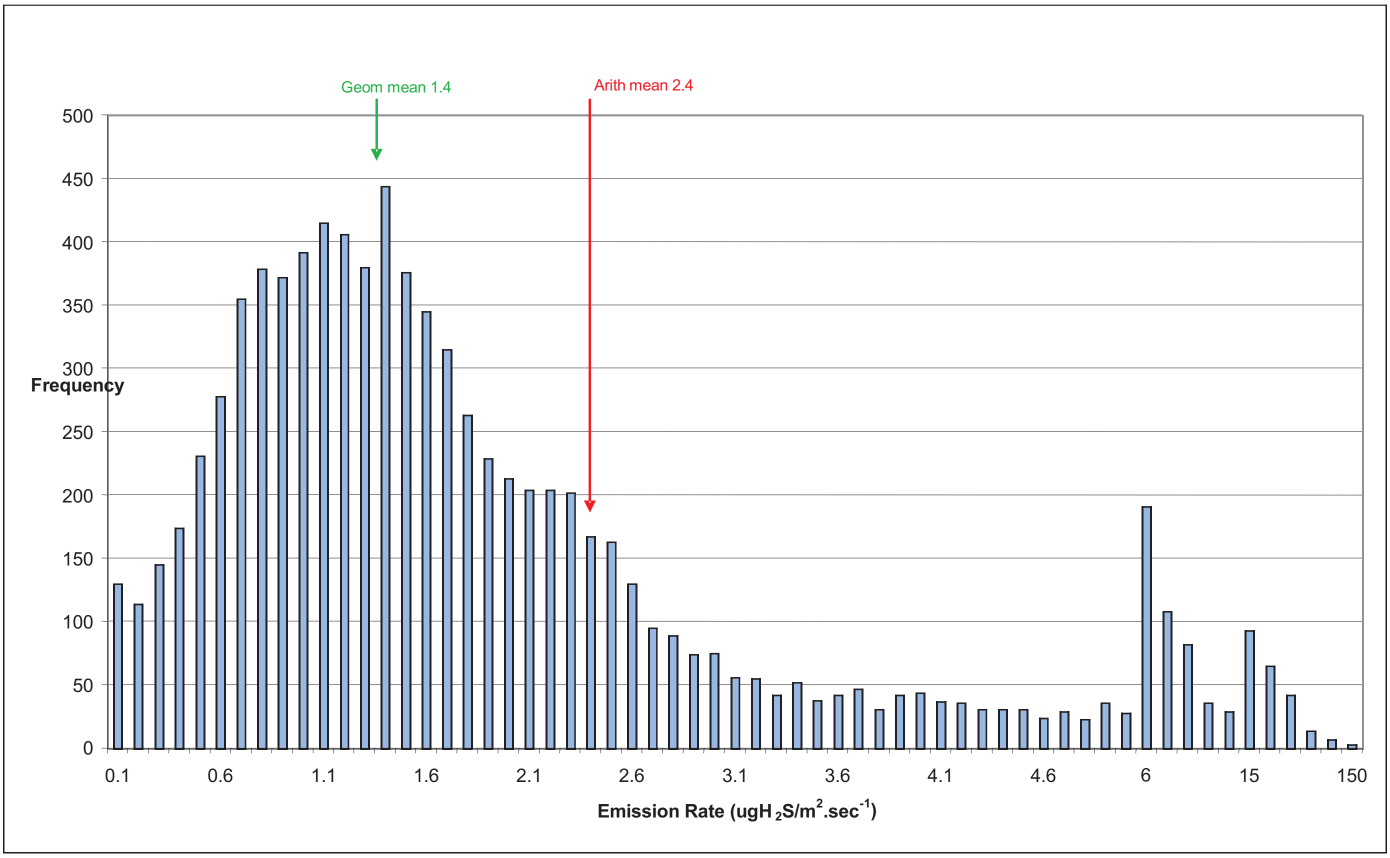

Figure 8: **Statistical analysis of “B” Works Trickling filters hourly emission rates**

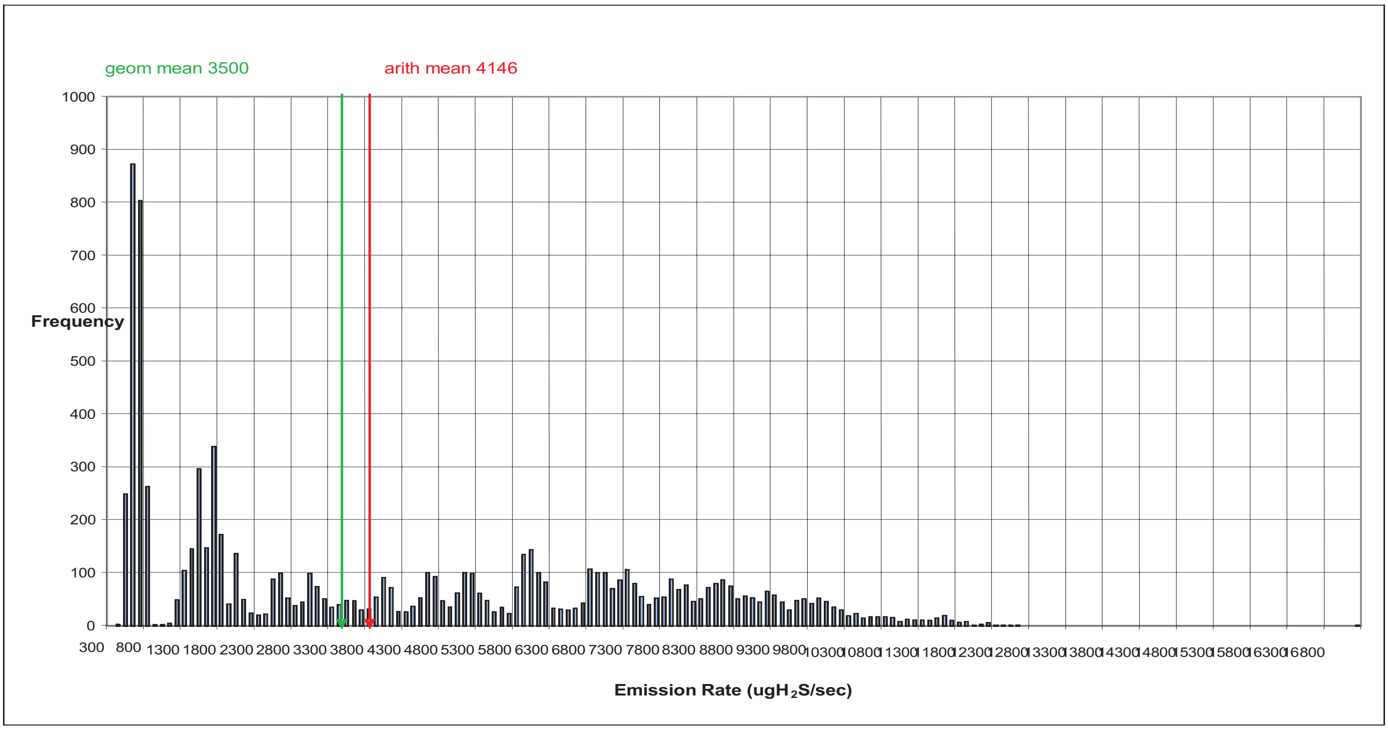

Figure 9: **Statistical analysis of Drop Structure hourly emission rate**

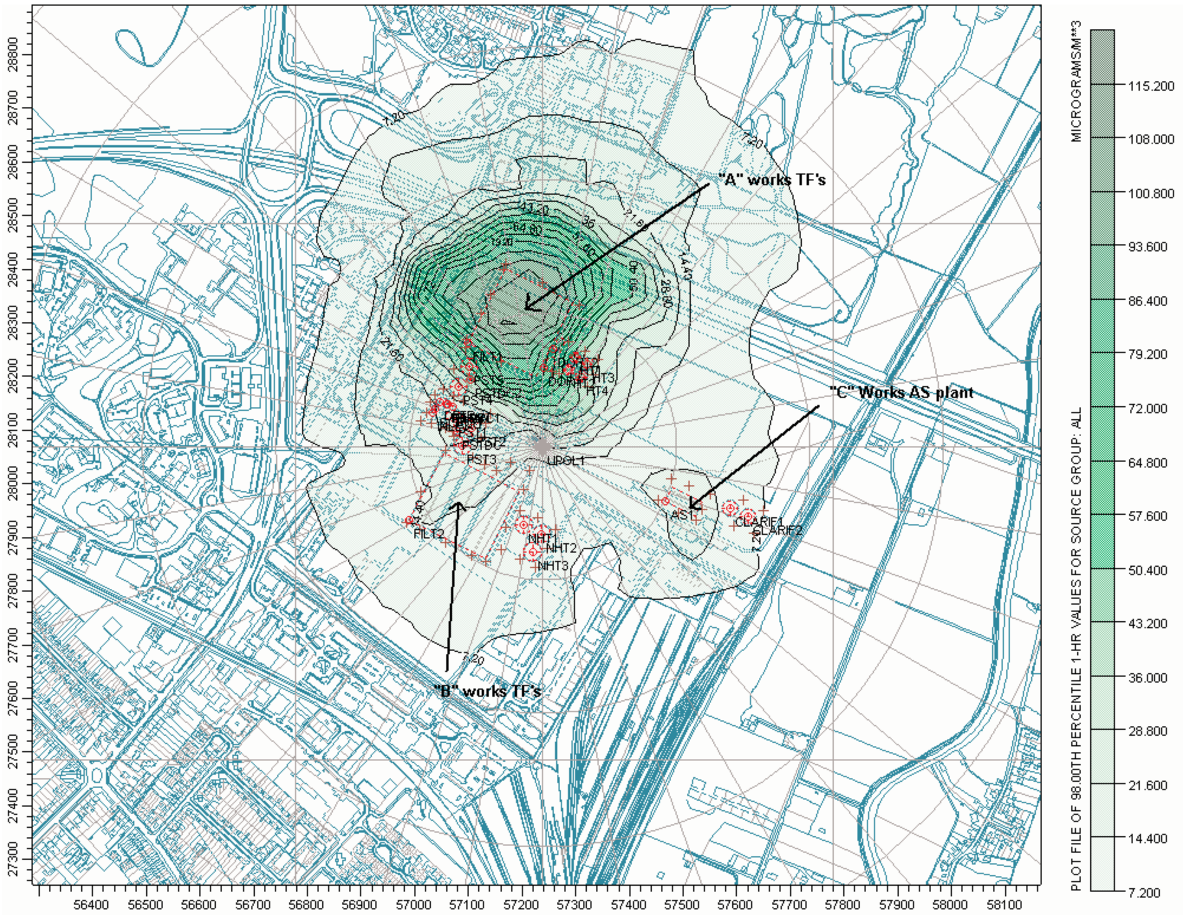

Figure 10: 98%ile Contour plot 2004 Constant emission rate

Figure 11: 98%ile Contour plot 2004 ODOURsim® emission rate

CONCLUSIONS

A good fit between the air dispersion plots using the calibrated ODOURsim® model emissions and the concentrations measured on site during the micrometeorological survey was observed. This indicates that the biological, chemical and physical equations used in the ODOURsim® model can be adequately calibrated to describe emissions from a WwTW for a given point in time.

The calibrated ODOURsim® model accurately predicted the emission rates for the identified sources for the concentrations measured on site for the validation day. This indicates that once the ODOURsim® model is calibrated, it can adequately describe emissions from a WwTW over a period of time, with a good degree of confidence.

The use of look-up-table (LUT) values yields a no discernable fit with the hourly concentrations measured on either the calibration or validation day. This stresses the importance of site visits and sampling in calibration of air dispersion models. Desk-based studies of sites using LUT values do not predict the spread of odour from a site with sufficient accuracy to undertake a FIDOL analysis.

The comparison of the 98%ile contour plots for the constant emission scenario (Figure 10) and the ODOURsim® variable emission rate scenario (Figure 11) indicates that the use of constant emission rates:

> Overestimates the odour impact from “A” works (North) filters.
>
> Overestimates the odour impact from “C” works (South East) AS plant.
>
> Underestimates the odour impact from Inlet and “B” works (South) filters.

The overall odour footprint for the works is overestimated if constant emission rates are used.

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