An Odour Dispersion Modelling Study of the Impact of the Proposed Turkey Rearing Houses at Hobb Lane, near Scounslow Green in Staffordshire

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AS Modelling & Data Ltd.
1. Introduction

AS Modelling & Data Ltd. has been instructed by Mercer Farming to use computer modelling to assess the impact of odour emissions from the proposed turkey rearing houses at Hobb Lane, near Scunslow Green in Staffordshire, ST14 8RQ.

Odour emission rates from the proposed turkey rearing houses have been assessed and quantified based upon an emissions model that takes into account the likely internal odour concentrations and ventilation rates of the poultry houses. The odour emission rates so obtained have then been used as inputs to an atmospheric dispersion model which calculates odour exposure levels in the surrounding area.

This report is arranged in the following manner:

- Section 2 provides relevant details of the site and potentially sensitive receptors in the area.
- Section 3 provides some general information on odour; details of the method used to estimate odour emissions from the proposed poultry houses; relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of odour.
- Section 4 provides some information about ADMS, the dispersion model used for this study and details the modelling parameters and procedures.
- Section 5 contains the results of the modelling.
- And Section 6 provides a discussion of the results and conclusions.
2. Background Details

The site of the proposed poultry rearing houses at Hobb Lane is in a rural area approximately 1,100 m to the south-west of the village of Scounslow Green in Staffordshire. The surrounding land is used primarily for arable farming although there are some meadows and wooded areas. The site is at an altitude of around 133 m; the surrounding land rises gently towards hills to the south and falls towards the Tad Brook to the north.

It is proposed that two new poultry houses which would each accommodate up to 6,000 turkeys be constructed on what is currently arable land to the south of Hobb Lane. The turkeys would be brought to the site at around 36 days old at a weight of approximately 1.5 kg and reared up to around 136 days old at which stage the female turkeys would weigh around 11 kg and the male turkeys would weigh around 17 kg. There would be approximately three flocks per year. The houses would be ventilated by uncapped ridge mounted fans, each with a short chimney.

There are some residences and commercial properties in the area surrounding the site of the proposed poultry houses at Hobb Lane. The nearest residences are at; High Trees Farm and Fenfield, between approximately 430 m and 460 m to the south-south-west; New Thorntree Farm, approximately 620 m to the north-east and Marlpit Farm, approximately 700 m to the east-south-east.

A map of the surrounding area is provided in Figure 1; the site of the proposed poultry houses at Hobb Lane is outlined in blue.
Figure 1. The area surrounding the site of the proposed poultry houses at Hobbs Lane.
3. Odour, Emission Rates, Exposure Limits & Background Levels

3.1 Odour concentration, averaging times, percentiles and FIDOR
Odour concentration is expressed in terms of European Odour Units per metre cubed of air (ouE/m³).
The following definitions and descriptions of how an odour might be perceived by a human with an average sense of smell may be useful; however, it should be noted that within a human population there is considerable variation in acuity of sense of smell.

- 1.0 ouE/m³ is defined as the limit of detection, in laboratory conditions.
- At 2.0 – 3.0 ouE/m³ a particular odour might be detected against background odours in an open environment.
- When the concentration reaches around 5.0 ouE/m³ a particular odour will usually be recognisable, if known, but would usually be described as faint.
- At 10.0 ouE/m³ most would describe the intensity of the odour as moderate or strong and if persistent, it is likely that the odour would become intrusive.

The character, or hedonic tone, of an odour is also important; typically odours are grouped into three categories:

Most offensive:
- Processes involving decaying animal or fish remains.
- Processes involving septic effluent or sludge.
- Biological landfill odours.

Moderately offensive:
- Intensive livestock rearing.
- Fat frying (food processing).
- Sugar beet processing.
- Well aerated green waste composting.

Less offensive:
- Brewery.
- Confectionery.
- Coffee roasting.
- Bakery.
Dispersion models usually calculate hourly mean odour concentrations and Environment Agency guidelines and findings from UK Water industry Research (UKWIR) are also framed in terms of hourly mean odour concentration.

The Environment Agency guidelines and findings from UKWIR use the 98th percentile hourly mean; this is the hourly mean odour concentration that is equalled or exceeded for 2% of the time period considered, which is typically one year. The use of the 98th percentile statistic allows for some consideration of both frequency and intensity of the odours.

At some distance from a source, it would be unusual if odour concentration remained constant for an hour and in reality, due to air turbulence and changes in wind direction, short term fluctuations in concentration are observed. Therefore, although average exposure levels may be below the detection threshold, or a particular guideline, a population may be exposed to short term concentrations which are higher than the hourly average. It should be noted that a fluctuating odour is often more noticeable than a steady background odour at a low concentration. It is implicit that within the models hourly averaging time and the Environment Agency guidelines and findings from UKWIR that there would be variation in the odour concentration around this mean i.e. there would be short periods when odour concentration would be higher than the mean.

The FIDOR acronym is a useful reminder of the factors that will determine the degree of odour pollution.

- Frequency of detection.
- Intensity as perceived.
- Duration of exposure.
- Offensiveness.
- Receptor sensitivity.

### 3.2 Environment Agency guidelines
In April 2011, the Environment Agency published H4 Odour Management guidance (H4). In Appendix 3 – Modelling Odour Exposure, benchmark exposure levels are provided. The benchmarks are based on the 98th percentile of hourly mean concentrations of odour modelled over a year at the site/installation boundary. The benchmarks are:

- 1.5 ou/m³ for most offensive odours.
- 3.0 ou/m³ for moderately offensive odours.
- 6.0 ou/m³ for less offensive odours.

Any modelled results that project exposures above these benchmark levels, after taking uncertainty into account, indicates the likelihood of unacceptable odour pollution.
3.3 UK Water industry Research findings

The main source of research into odour impacts in the UK has been the wastewater industry. An in-depth study of the correlation between modelled odour impacts and human response was published by UKWIR in 2001. This was based on a review of the correlation between reported odour complaints and modelled odour impacts in relation to nine wastewater treatment works in the UK with on-going odour complaints. The findings of this research and subsequent UKWIR research indicated the following. Based on the modelled 98th percentile of hourly mean concentrations of odour:

- At below 5.0 ouₐ/m³, complaints are relatively rare, at only 3% of the total registered.
- At between 5.0 ouₐ/m³ and 10.0 ouₐ/m³, a significant proportion of total registered complaints occur, 38% of the total.
- The majority of complaints occur in areas of modelled exposures of greater than 10.0 ouₐ/m³, 59% of the total.

3.4 Choice of Odour Benchmarks for this Study

Odours from poultry rearing are usually placed in the moderately offensive category. Therefore, for this study, the Environment Agency’s benchmark for moderately offensive odours, a 98th percentile hourly mean of 3.0 ouₐ/m³ over a one year period, is used to assess the impact of odour emissions from the proposed poultry unit at potentially sensitive receptors in the surrounding area.

3.5 Quantification of Odour Emissions

Odour emission rates from turkey rearing houses depend on many factors and are highly variable. At the beginning of a crop cycle, when birds are smaller, litter is clean and only minimum ventilation is normally required, the odour emission rate may be relatively small. Towards the end of the crop, odour production within the poultry housing increases rapidly and ventilation requirements are greater, particularly in hot weather; therefore, emission rates are considerably greater than at the beginning of the crop.

Peak odour emission rates are likely to occur when the housing is cleared of spent litter at the end of each crop. There is little available information on the magnitude of this peak emission, but it is likely to be greater than any emission that might occur when there are birds in the house. There are measures that can be taken to minimise odour production whilst the housing is being cleared of spent litter. The time taken to perform the operation is usually around an hour or two per shed and there is usually some discretion as to when the operation is carried out. Therefore, to avoid high odour levels at nearby sensitive receptors it may be possible to time the operation to coincide with winds blowing in a favourable direction. It should be noted that it is normal to maintain ventilation during clearing out.

To calculate an odour emission rate it is necessary to know the internal odour concentration and ventilation rate of the poultry house. For the calculation, the internal concentration is assumed to be a function of the age of the crop and the stocking density.
The internal concentrations used in the calculations increase linearly from 300 ou_{E}/m^{3} at day 1 of the crop, to 1,000 ou_{E}/m^{3} at day 15 of the crop and to 1,500 ou_{E}/m^{3} at day 35 of the crop. These figures are obtained from a review of available literature.

The ventilation rates used in the calculations are based on industry standard practices and bird growth factors and where available, site specific practices. Target internal temperature is 18 Celsius at the beginning of the crop and is decreased to 14 Celsius by day 82 of the crop. If the external temperature is 4 Celsius, or more, lower than the target temperature, minimum ventilation only is assumed for the calculation. Above this, ventilation rates are increased in proportion to the difference between ambient temperature and target internal temperature. A maximum transitional ventilation rate (30% of the maximum possible ventilation rate) is reached when the temperature is 1 degree above the target temperature. A high ventilation rate (60% maximum possible ventilation rate) is reached when the temperature is 4 degrees above target and if external temperature is above 33 Celsius the maximum ventilation rate is assumed.

At high ventilation rates, it is likely that internal odour concentrations fall because odour is extracted much faster than it is created. Therefore, if the calculated ventilation rate exceeds that required to replace the volume of air in the house every 5 minutes, internal concentrations are reduced (by a factor of the square root of 12 times the shed volume/divided by the ventilation rate as an hourly figure).

Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. Both the crop length and period the housing is empty can be varied. An estimation of the emission during the cleaning out process can also be included. In this case it is assumed that the houses are cleared sequentially and each house takes 2 hours to clear.

In this case it is assumed for the calculations that the crop length is 100 days, with 10% thinning of the birds at day 91 and that there is an empty period of 14 days after each crop. To provide robust statistics, three sets of calculations were performed; the first with the first day of the meteorological record coinciding with day 1 of the crop cycle, the second coinciding with day 38 of the crop and the third coinciding with day 76 of the crop. A summary of the emission rates used in this study is provided in Table 1. It should be noted that the figures in this table refer to the whole of the crop length and are based upon the initial number of birds stocked. Most figures quoted in literature are figures obtained from the latter stages of the crop cycle and are based on actual bird numbers at the time and therefore should not be compared directly to the AS Modelling & Data Ltd. figures in the table. The specific odour emission rate used for the clearing process is approximately 15.35 ou_{E}/bird/s (as stocked) and the 98th percentile emission rate is approximately 10.00 ou_{E}/bird/s (as stocked). As an example, a graph of the specific emission rate over the first year of the meteorological record for each of the three crop cycles is shown in Figure 2.
Table 1. Summary of odour emission rates (average or maximum of all three cycles)

<table>
<thead>
<tr>
<th>Season</th>
<th>Average Night-time</th>
<th>Average Day-time</th>
<th>Maximum Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>2.624</td>
<td>3.214</td>
<td>10.097</td>
</tr>
<tr>
<td>Spring</td>
<td>3.657</td>
<td>4.746</td>
<td>11.173</td>
</tr>
<tr>
<td>Summer</td>
<td>4.853</td>
<td>5.923</td>
<td>11.926</td>
</tr>
<tr>
<td>Autumn</td>
<td>3.165</td>
<td>3.784</td>
<td>11.150</td>
</tr>
</tbody>
</table>

Figure 2. Specific emission rate over the first year of each of the three crop cycles

<table>
<thead>
<tr>
<th>Emission Rate (ou/s per bird as stocked during crop)</th>
<th>Autumn</th>
<th>Summer</th>
<th>Spring</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.784</td>
<td>3.165</td>
<td>3.784</td>
<td>2.547</td>
<td>3.069</td>
</tr>
<tr>
<td>3.069</td>
<td>4.853</td>
<td>3.657</td>
<td>2.586</td>
<td>2.329</td>
</tr>
<tr>
<td>3.214</td>
<td>2.547</td>
<td>4.746</td>
<td>3.069</td>
<td>2.329</td>
</tr>
<tr>
<td>Winter Average</td>
<td>2.547</td>
<td>4.746</td>
<td>3.069</td>
<td>2.329</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.784</td>
<td>3.784</td>
<td>2.547</td>
<td>3.069</td>
</tr>
</tbody>
</table>

Table 2. Summary of odour emission rates (average or maximum of all three cycles)
4. The Atmospheric Dispersion Modelling System (ADMS) and model parameters

The Atmospheric Dispersion Modelling System (ADMS) ADMS 5 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth, and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

ADMS has a number of model options including: dry and wet deposition; NO\textsubscript{x} chemistry; impacts of hills, variable roughness, buildings and coastlines; puffs; fluctuations; odours; radioactivity decay (and \(\gamma\)-ray dose); condensed plume visibility; time varying sources and inclusion of background concentrations.

ADMS has an in-built meteorological pre-processor that allows flexible input of meteorological data both standard and more specialist. Hourly sequential and statistical data can be processed, and all input and output meteorological variables are written to a file after processing.

The user defines the pollutant, the averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits, which can vary from country to country, and are subject to revision.
4.1 Meteorological data

Computer modelling of dispersion requires hourly sequential meteorological data and to provide robust statistics the record should be of a suitable length; preferably four years or longer.

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS). The GFS is a spectral model and data are archived at a horizontal resolution of 0.5 degrees, which is approximately 50 km over the UK (latterly 0.25 degrees, or approximately 25 km). The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional observational records may be over represented, this is because the instrumentation used may not record wind speed below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

- Traditional observational records may include very local deviations from the broad-scale wind flow that would not necessarily be representative of the site being modelled; these deviations are difficult to identify and remove from a meteorological record. Conversely, local effects at the site being modelled are relatively easy to impose on the broad-scale flow and provided horizontal resolution is not too great, the meteorological records from NWP data may be expected to represent well the broad-scale flow.

- Information on the state of the atmosphere above ground level which would otherwise be estimated by the meteorological pre-processor may be included explicitly.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 3a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the site of the proposed poultry houses is shown in Figure 3b. Note that elsewhere in the modelling domain, modified wind roses may differ and that the resolution of the wind field is 200 m.
Figure 3a. The wind rose. GFS derived data, for 52.858 N, 1.875 W, 2011 - 2014
Figure 3b. The wind rose. FLOWSTAR data, for the site of the proposed poultry houses.
4.2 Emission sources

Emissions from the uncapped chimneys of the ridge mounted fans that would be used to ventilate the proposed poultry houses are represented by three point sources per house within ADMS (PR1 and PR2 a, b & c). Details of the point source parameters are shown in Table 2 and the positions of the point sources may be seen in Figure 4.

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Height (m)</th>
<th>Diameter (m)</th>
<th>Efflux velocity (m/s)</th>
<th>Emission temperature (°C)</th>
<th>Emission rate per source (ouE/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR1 and PR2 a, b &amp; c</td>
<td>6.5</td>
<td>0.8</td>
<td>11.3</td>
<td>Variable¹</td>
<td>Variable¹</td>
</tr>
</tbody>
</table>

1. Dependent on ambient temperature and target temperature.

4.3 Modelled buildings

The structure of the poultry houses may affect the odour plumes from the point sources. Therefore, the proposed buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 4 where they are marked by grey rectangles.

Figure 4. The positions of modelled buildings and sources
4.4 Discrete receptors
Five discrete receptors have been defined at a selection of nearby residences and commercial premises. The receptors are defined at 1.5 m above ground level within ADMS and their positions may be seen in Figure 5, where they are marked by enumerated pink rectangles.

4.5 Nested Cartesian grid
To produce the contour plots presented in Section 5 of this report, a nested Cartesian grid has been defined within ADMS. The grid receptors are defined at 1.5 m above ground level within ADMS. The positions of the receptors may be seen in Figure 5 where they are marked by green crosses.

4.6 Terrain data
The area around Hobb Lane has some hills and steep slopes; therefore, terrain data has been considered in the modelling. The terrain data used is derived from the Ordnance Survey 50 m Digital Elevation Model (DEM). The 50 m DEM data has been resampled at 50 m for use within ADMS. The terrain domain is 6,400 m by 6,400 m and FLOWSTAR is run at a resolution of 32 x 32 points; therefore, the effective model resolution is 200 m.

4.7 Other model parameters
A fixed surface roughness length of 0.3 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.2 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and the stability and therefore increases predicted ground level concentrations.
Figure 5. The discrete receptors and nested Cartesian grid receptors.
5. Details of the Model Runs and Results

For this study ADMS was run with the terrain module of ADMS (FLOWSTAR) and with the calms module of ADMS.

ADMS was effectively run twelve times, once for each year of the four year meteorological record and for each of the three crop cycles. Statistics for the annual 98th percentile hourly mean odour concentration at each receptor were compiled for each of the twelve runs.

A summary of the results of these twelve runs at the discrete receptors is provided in Table 3 where the maximum annual 98th percentile hourly mean odour concentration is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentration is shown in Figure 6.

In Table 3, predicted odour exposures in excess of the Environment Agency’s benchmark of 3.0 ouE/m³ as an annual 98th percentile hourly mean are coloured blue; those in the range that UKWIR research suggests gives rise to a significant proportion of complaints, 5.0 ouE/m³ to 10.0 ouE/m³ as an annual 98th percentile hourly mean, are coloured orange and predicted exposures likely to cause annoyance and complaint are coloured red.
Table 3. Predicted maximum annual 98th percentile hourly mean odour concentrations at the discrete receptors

<table>
<thead>
<tr>
<th>Receptor number</th>
<th>X(m)</th>
<th>Y(m)</th>
<th>Maximum annual 98th percentile hourly mean odour concentration (ouE/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>408154</td>
<td>328557</td>
<td>0.88</td>
</tr>
<tr>
<td>2</td>
<td>408039</td>
<td>328603</td>
<td>0.69</td>
</tr>
<tr>
<td>3</td>
<td>408937</td>
<td>329351</td>
<td>0.75</td>
</tr>
<tr>
<td>4</td>
<td>409132</td>
<td>328815</td>
<td>0.48</td>
</tr>
<tr>
<td>5</td>
<td>407988</td>
<td>329853</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration in the area surrounding the proposed poultry unit.
6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mercer Farming to use computer modelling to assess the impact of odour emissions from the proposed turkey rearing houses at Hobb Lane, near Scounslow Green in Staffordshire. ST14 8RQ.

Odour emission rates from the proposed turkey rearing houses have been assessed and quantified based upon an emissions model that takes into account the likely internal odour concentrations and ventilation rates of the poultry houses. The odour emission rates so obtained have then been used as inputs to an atmospheric dispersion model which calculates odour exposure levels in the surrounding area.

At all receptors considered, the maximum predicted 98th percentile hourly mean odour concentrations are below the Environment Agency’s benchmark for moderately offensive odours, a 98th percentile hourly mean of 3.0 ouc/m³ over a one year period.
7. References

Chartered Institution of Water and Environmental Management website. Control of Odour.  

http://a0768b4a8a31e106d8b0-50dc-802554eb38a24458b98f72d550b.r19.cf3.rackcdn.com/geo0411bqm-e-e.pdf

E.T. Hayes, T.P. Curran, V.A. Dodd. Odour and ammonia emissions from intensive poultry units in Ireland