

South Norfolk Council

**PM₁₀ Emissions from
Poultry Rearing**

Detailed Assessment

August 2006

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1 Introduction

The Air Quality Updating and Screening Assessment¹ (USA) undertaken for South Norfolk Council (SNC) examined a range of possible particulate matter sources. This assessment highlighted that emission of fine particulate matter (PM₁₀) from poultry rearing may result in increases in concentrations in the local environment that exceeded relevant air quality objectives. The USA uses relatively simple methods to identify pollution sources that might result in exceedances of objectives. If these simple methods show a potential problem then a more detailed assessment using more sophisticated approaches is undertaken to confirm whether an air quality problem exists.

Ove Arup and Partners Ltd (Arup) was commissioned by SNC to undertake a detailed assessment using dispersion modelling and on-site monitoring. This report details the results of a more detailed assessment undertaken to assess in detail the likely impact of PM₁₀ emissions from poultry sheds.

¹ Air Quality Updating and Screening Assessment, South Norfolk Council, NETCEN, June 2003

2 Background

2.1 Relevant Air Quality Objectives

Air quality objectives have been introduced in England for various pollutants including PM₁₀. These objectives are target values that local authorities should work towards achieving by a particular date. For PM₁₀ two objectives have been introduced. Firstly, an annual mean objective of 40µg/m³, and secondly a daily mean of 50µg/m³ not to be exceeded more than 35 times a year. Both have a target date to be achieved of 31 December 2004. The same values have also been introduced as limit values for air quality as a result of European legislation with a very similar target date.

Where the objective values are not expected to be achieved by their target date, the local authority must declare an Air Quality Management Area (AQMA) and prepare an action plan detailing measures intended to improve air quality.

Recent announcements from the European Community suggest that the target dates for achievement of the limit values will be extended by at least 5 years. These amendments have not been finalised and therefore are not currently in UK legislation.

2.2 Existing Air Quality Information

There is no local monitoring information available in the area for PM₁₀ however estimates are available on the National Air Quality Archive. For 2005 and the grid square centred on 617500, 288500 the estimated annual average concentration is 20.2µg/m³.

2.3 Background Information

Agriculture in the UK is acknowledged as a significant source of PM₁₀. A recent study² estimated that annual emissions from agriculture were in the range 10-23.7 ktonnes/annum with an average estimate of 16.9 ktonnes/annum (figures for 1998) compared with national emissions of 184 ktonnes/annum reported for 1997 in the National Air Quality Strategy³. Housed poultry is estimated to be the source of nearly half of the total agricultural PM₁₀ emissions in the UK; the average figure reported being 8.7 ktonnes/year. Thus, poultry houses are one of the more significant sources of PM₁₀ in the UK being responsible for some 5% of UK emissions.

These emissions estimates were based on a literature review that examined all sources of particulate matter emissions from agriculture. Although there is only limited information available regarding emissions livestock buildings this the one source where emission rates have been directly measured in the UK (in a collaborative study with three other European countries under taken by Takai *et al*)⁴. The study measured total inhalable dust and respirable dust, the instruments used to measure respirable had a 50% cut off at 5µg/m³ and hence are not compatible with the PM₁₀ air quality standard. However, the measurements were considered sufficient to estimate PM₁₀ emission rates. It was noted that the measurements were taken in poultry houses considered to be relatively old and that this may have resulted in overestimates in emissions.

The inhalable and respirable dust emission rates measured averaged for the four study countries and those for the UK are detailed below in Table 1.

² Atmospheric emissions of particulates from agriculture: a scoping study, MAFF research report, WA 0802, 2000

³ The Air Quality Strategy for England, Scotland, Wales and Northern Ireland Working Together for Clean Air, January 2000

⁴ Concentrations and Emissions of Airborne Dust in Livestock Buildings in Northern Europe, Takai, H. et al. J. agric. Engng. Res. 70, 59-77, 1998.

Table 1 Particulate matter emission rates reported by Takai et al

Emissions kg/yr/500kg weight of bird	Average – four countries	Average – UK
Respirable dust	4.42	3.27
Inhalable dust	27.7	27.5

As can be seen from the above, the respirable fraction (i.e. that closest to PM₁₀) represents about 16% of the total emissions in the measurements made for this study. These measurements are reported in terms of emissions per weight of bird, obviously this changes throughout the rearing cycle but typically broilers are reared to between 2-3 kg before harvesting.

In the Environment Agency application form for a Pig and Poultry Rearing permit (ILF1) an emission rate of 0.1 kg/yr/bird is suggested for calculating particulate matter emissions. Taking an average bird weight during a rearing cycle of 1kg the Environment Agency emission factors are about double those reported by Takai *et al.*

The Updated Screening and Assessment report used the Takai emission factor for **total suspended particulates** to conclude that a further assessment would be required. This was based on calculating the allowable emission rate of 0.77 tonnes per year of particulate matter and assuming that all particles emitted were in the respirable range for a typical poultry farm of 21,500 birds.

In an subsequent assessment undertaken by Arup for SNC⁵ the Environment Agency emission factors were used to model the emissions from Elm Tree Farm where there were concerns regarding the potential impact of PM₁₀ emissions. This farm houses 61,000 birds and is located relatively close to residential housing. Modelling of the emissions from this site indicated that there was a possibility that the 24 hour objective for PM₁₀ might be exceeded. However, since this modelling was based on standard emission factors rather than specific factors measured at the site that there was considerable uncertainty regarding the results. The dispersion modelling results could be improved by taking on-site measurements of the emissions, however, it was not possible to undertake this type of measurements due to problems accessing test sites.

Therefore, it was decided to measure concentrations of PM₁₀ near to an operational poultry rearing facility to assess the potential air quality impacts in the area. This monitoring assessment is described in the next section.

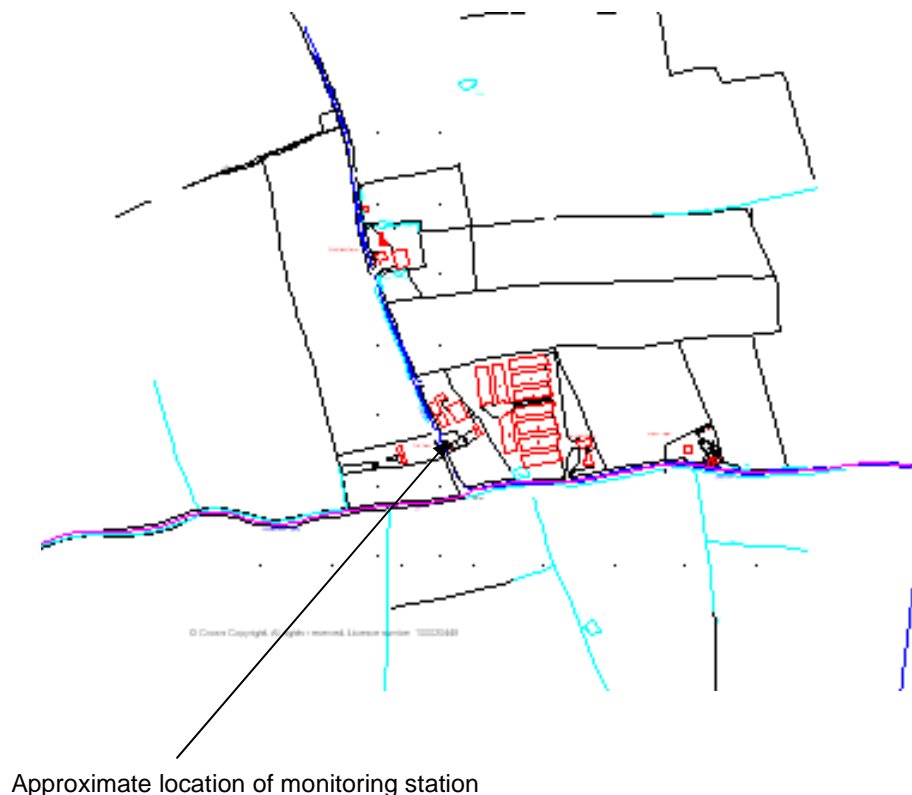
⁵ Ove Arup and Partners Ltd, PM10 Emissions from Poultry Rearing, Initial Modelling Assessment, August 2004, Report prepared for South Norfolk Council.

3 Monitoring of PM₁₀

Monitoring is being carried out at a site within Frith Farm, Frith Way, Great Moulton (See Figure 1). There is a large poultry farm (Lostlands Farm) next to Frith Farm; this is a large poultry farm that has reported to SNC that up to 250,000 birds are kept on site, with 25,000 birds in ten sheds. For the monitoring it was considered that it was important to use a method of measurement that would allow the results to be directly compared with the UK air quality objective without correction. Therefore, a Partisol type monitor was installed at the monitoring site to measure 24 hour average PM₁₀ concentrations. However, it was also recognised that monitoring 24 hour averages would not allow detailed directional analysis to determine the likely source of the emissions. This would require an instrument that would be able to measure particulate matter concentrations over a shorter averaging period; hence a TEOM type monitor was also installed at the site together with a wind speed and direction gauge.

The instruments were installed and operated by TRL Ltd and monitoring began on 23 July 2005. The site is visited at least every fortnight to replace the filters in the Partisol or when the site telemetry indicates a possible fault. The TEOM is set to report hourly PM₁₀ average concentrations (and the results processed by TRL to provide 24 hour average concentrations). The wind speed and direction gauge records hourly average wind speed and direction. The Partisol monitor measures for a 24 hour average.

Figure 1 : Location of Monitoring Site



4 Results of PM₁₀ Monitoring

This report describes results for the period 23 July – 22 December 2005 and 8 April – 28 June 2006.

4.1 Equipment Performance

The equipment experienced various operational problems associated with power supply problems and actual equipment failure. In the monitoring period there were 149 days when 24 hour averages were obtained from both the Partisol and TEOM monitors.

4.2 Basic Results – Partisol Monitor

During the monitoring period, the basic results from the Partisol Monitor are as follows:

Average Concentration: 21.7µg/m³

Maximum 24 Hour Average: 87.1µg/m³

Minimum 24 Hour Average: 4.2µg/m³

Number of 24 Hour Averages > 50µg/m³: 6

4.3 Basic Results – TEOM Monitor

Based on the monitoring to date, the basic results from the TEOM monitor are as follows:

Average Concentration: 18.1µg/m³

Maximum 24 Hour Average: 50.3µg/m³

Minimum 24 Hour Average: 6.0µg/m³

Number of 24 Hour Averages >50µg/m³: 1

4.4 Correlation Between Partisol and TEOM results

It is known that the TEOM instrument will generally underestimate concentrations compared with a Partisol owing to loss during heating of the sample. A correction factor of 1.3 is recommended in the absence of any locally derived figure. For this monitoring programme it is possible to directly derive a correction factor. The results from each instrument have been plotted as an XY graph and a linear regression undertaken. The results are shown in Figure 2 below.

The regression shows that the TEOM results require a correction of 1.228 to account for the underreading of the instrument. This is slightly lower than that normally observed but most measurements of PM₁₀ have been undertaken in urban areas where traffic is a much greater contributor to local concentrations. Hence the nature of the particulate matter is likely to be substantially different at this site resulting in a different correction factor. Applying a factor of 1.228 to the measured TEOM values results in 6 exceedances of 50µg/m³ during the monitoring period to date.

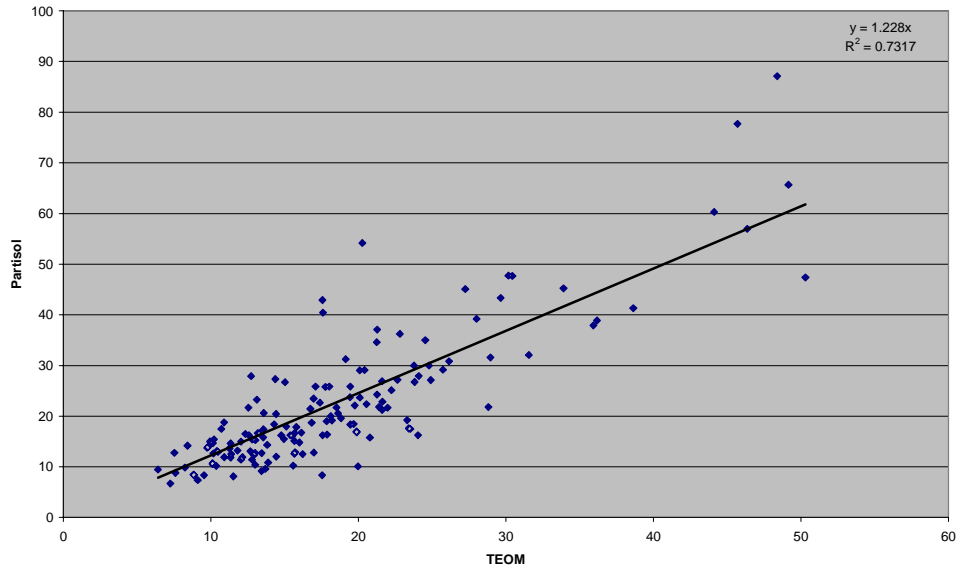


Figure 2 Correlation between TEOM and Partisol PM₁₀ Measurements

4.5 Analysis of Observed PM₁₀ Concentrations by Wind Direction

The results have been analysed to examine the influence of wind direction on the observed concentrations. The results have firstly been processed to determine the average PM₁₀ concentration as a function of wind direction. The measured values have been sorted by wind direction into 30° sectors and the average concentration calculated. The results have then been further analysed by examining various percentile concentrations. If there is a significant source of particulate matter in the area it would be expected that there would be more frequent observations of high concentrations when the wind is blowing from the source to the monitoring equipment and that average concentrations would be higher. Note that due to the relative location of the monitoring site and the various poultry sheds, concentrations of PM₁₀ would be affected by wind directions over a relatively large arc. Therefore it is not appropriate to analyse these results further by wind direction to obtain more information on the source of the particulate matter. The results are shown in Figures 3 and 4 below.

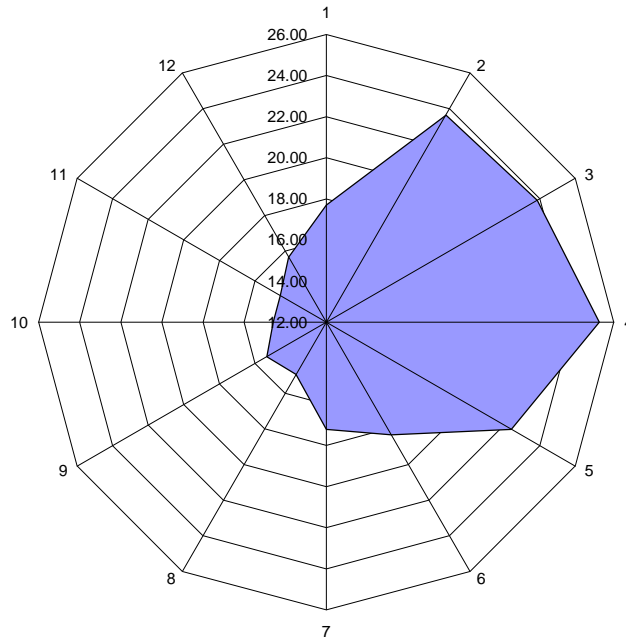


Figure 3 Pollution Rose of Average PM₁₀ Concentrations

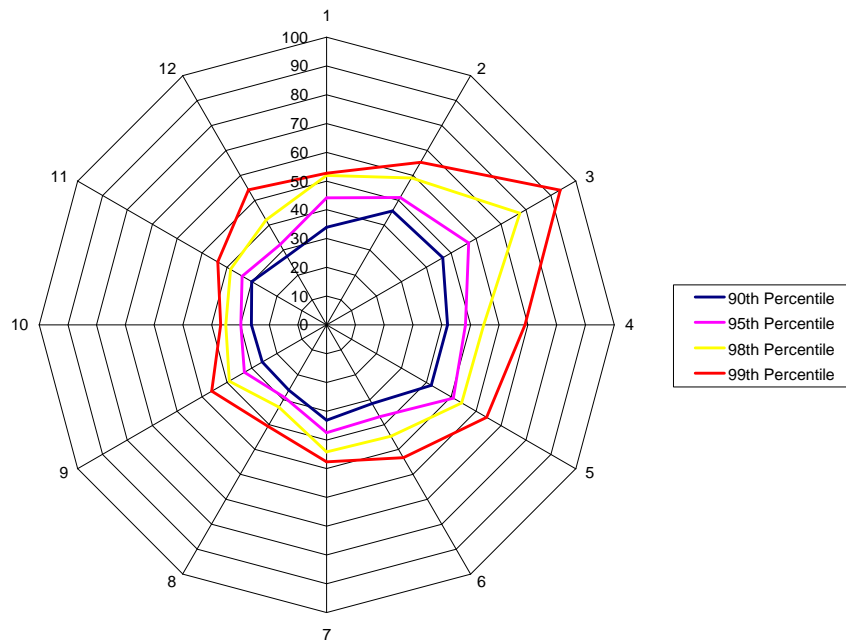


Figure 4 Pollution Rose of Percentile PM₁₀ Concentrations

As can be seen from the results, there is a clear influence in PM₁₀ concentrations with easterly winds (i.e. from the direction of the poultry sheds). The average PM₁₀ concentration increases by a maximum of nearly 12µg/m³ for easterly winds and the 95th (and above) percentile concentrations nearly double. Similar analysis of monitoring results near a poultry shed by the Environment Agency concluded that this was clear evidence of the influence of sheds on particulate matter concentrations.

To assess the contribution of the poultry operations on average concentrations monitored at the site the following assumptions were made:

1. The average concentrations measured from directions where the poultry sheds could not influence the results represent the average concentration if the poultry emissions do not influence the site.
2. The concentrations from the arc of 15-135° are all influenced by the poultry farm emissions.

Making these assumptions the increase in PM₁₀ concentrations as a result of the emissions from the farm is 2.6µg/m³. A similar analysis has been undertaken for the hourly percentile values taking first the percentile values for the sector unaffected by emissions from the farms and then comparing these with the values for the entire data set. The results are shown in Table 2 below.

Percentile	Data set unaffected by farm emissions	Entire data set
95	29.3	34.2
96	34.6	40.3
97	38.2	44.5
98	41.1	47.8
99	46.9	55.6

Table 2 Percentiles of hourly PM₁₀ concentrations measured at Frith Farm.

The results show that there is an elevation in percentile concentrations when the easterly sector is included in the data suggesting that the farm emissions could increase the 99th percentile of hourly means by approximately 9µg/m³.

The same analysis cannot be undertaken for the 24 hour mean concentrations since the wind direction varies throughout the day.

4.6 Significance of the Monitoring Results

The results of the monitoring found 6 exceedances of the 50µg/m³ threshold for the 24 hour mean concentrations during the seven month monitoring undertaken. However, the UK Air Quality Objectives allow up to 35 exceedances in a year. To estimate the total annual number of exceedances from the five months of monitoring results can be undertaken by simple extrapolation to 12 months. Given an average of approximately one exceedance of the threshold each month the total annual number of would be 12. A slightly more sophisticated approach can be taken using information from other monitoring sites nearby and observing when exceedances have occurred. In this area this is difficult to carry out

because there are very few monitoring sites nearby that are in similar locations to the Frith Farm site.

Data have been obtained from the National Air Quality Archive for the daily mean PM₁₀ concentrations for Norwich Town Centre and for Harwell for the initial five months of monitoring. While neither is close to the site they do provide some general information regarding trends in PM₁₀ concentrations in England. The information is shown below.

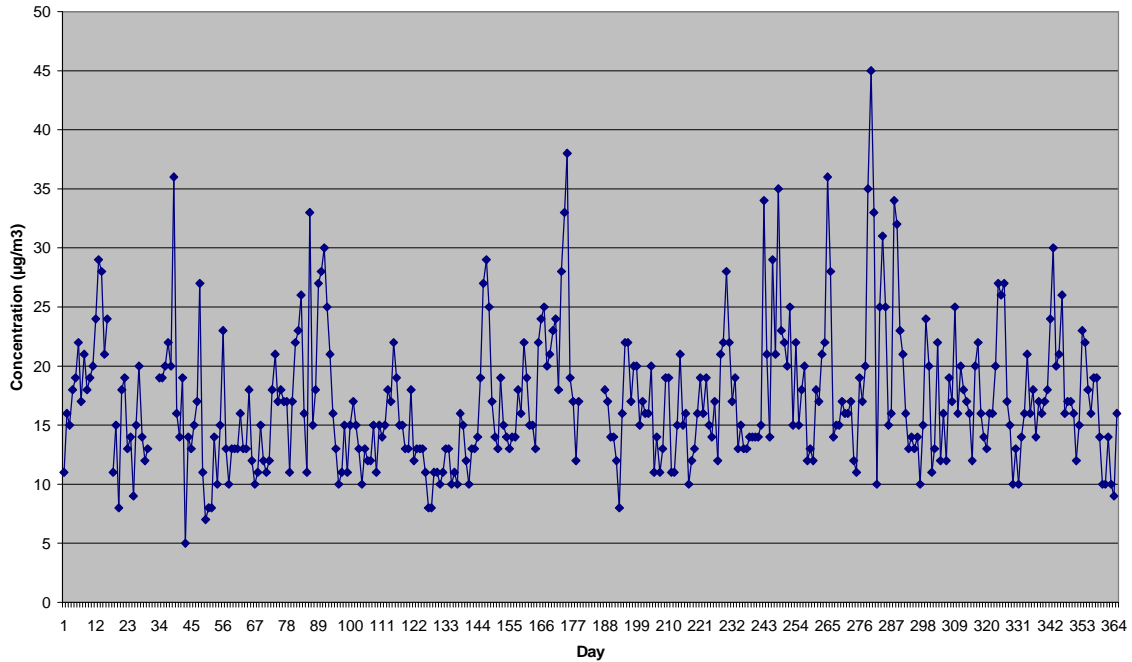


Figure 5 Daily Mean Concentrations of PM₁₀ at Norwich

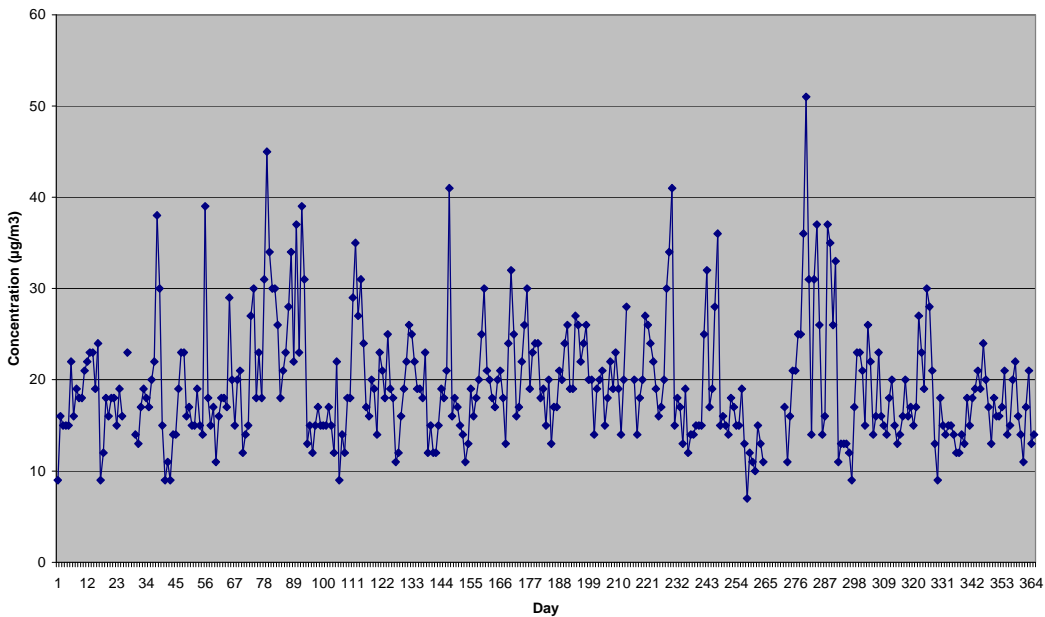
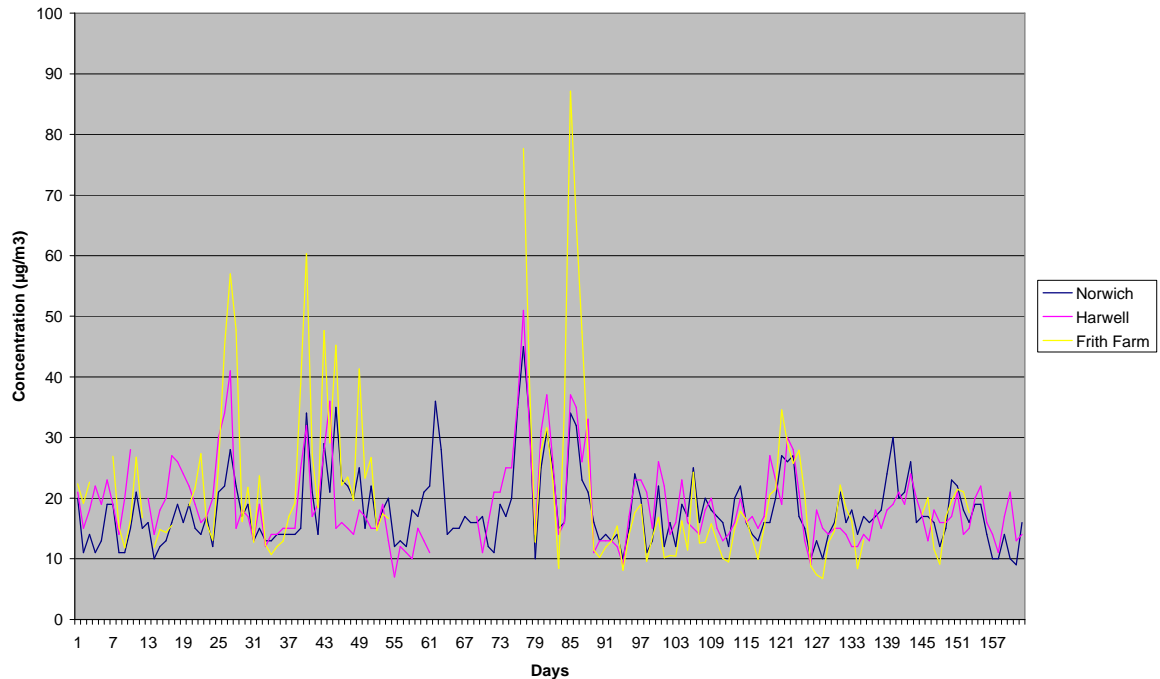


Figure 6 Daily Mean PM₁₀ Concentrations Observed at Harwell

As can be seen from the data, higher concentrations are relatively evenly spread throughout the year. It is interesting to note that no exceedances of the $50\mu\text{g}/\text{m}^3$ threshold were observed at either site even though Norwich is in a town centre location. The results from all three sites have been collated together and plotted on the same graph and shown below in Figure 7.

Figure 7 Results of Daily Mean PM₁₀ Concentrations at three sites 2005



This analysis shows that most of the observed exceedances at Frith Farm coincided with peaks in concentrations observed at other sites. This would be expected as it is likely that background concentrations need to be higher than normal to combine with the increased concentrations as a result of emissions from the poultry sheds. For a significant proportion of the monitoring programme, the PM₁₀ concentrations observed at all three sites were remarkably similar (from day 90 onwards for instance).

A similar situation was noted for the monitoring carried out during 2006 as shown in Figure 8.

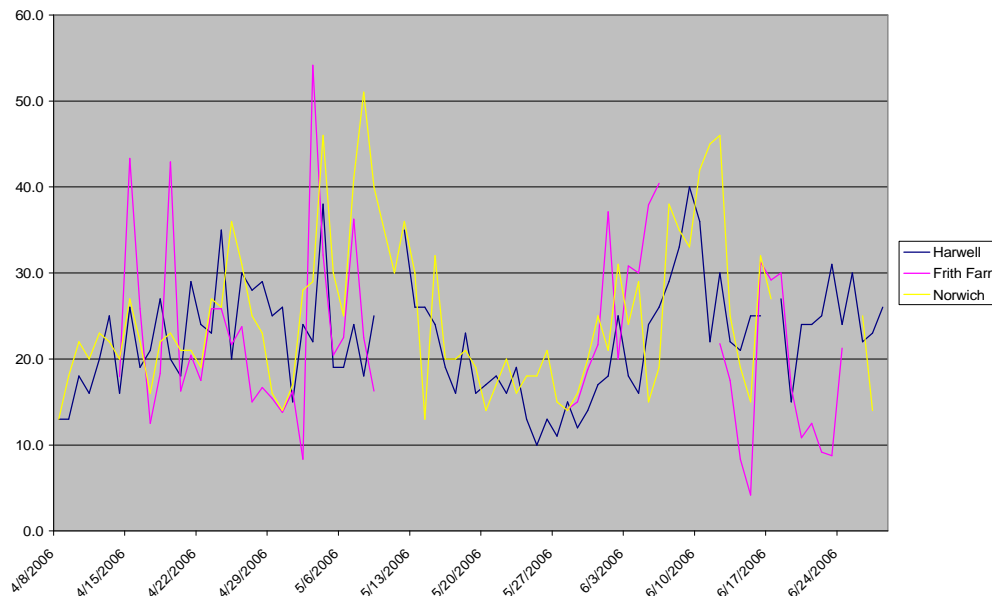


Figure 8 Results of daily mean PM₁₀ Concentrations at three sites 2006

Mean concentrations observed at Frith Farm are well within the UK Air Quality Objective, although the initial results were obtained for only five months in a calendar year. However, examination of the results from the two other sites suggests that this is likely to be representative of concentrations for the whole year (the ratio of mean concentrations during the monitoring programme compared with whole year being 1.06 and 0.98 for Norwich and Harwell respectively).

Therefore it can be concluded that PM₁₀ concentrations at the monitoring site are likely to meet the UK Air Quality Objective, however, there is a further residential property on the poultry farm itself that could be more affected by the emissions. In order to assess the potential concentrations at this site a short dispersion modelling study has been undertaken. This is described in the following section.

4.7 Dispersion Modelling Study

4.7.1 Modelling Methods and Input Data

To assess the likely impacts at the residential property on the poultry farm a dispersion modelling study has been carried out. This study was designed to determine the predicted differences between the concentrations at the monitoring site and those at the property. The model used was AERMOD (Trinity Consultants Version 5.1). This is a preferred dispersion model for the United States Environmental Protection Agency (USEPA) and is widely applied in the UK for similar studies and is considered to be an advanced model in DEFRA guidance.

The model requires information concerning the sources of emissions (i.e. location, size and emission rates), local meteorology and the nature of the local terrain. 10 areas sources have been used in the modelling to represent each of the sheds, the dimensions of the sources were taken from a detailed OS plan for the area obtained in DXF format. It was assumed that the houses were side ventilated and therefore the emission height was set at 2m.

Meteorological data were taken from the Wattisham site for the year 1994. The data were obtained in ADMS format from Trinity Consultants and processed into a form suitable for AERMOD using the AERMET Pro Processor with the following local terrain information:

- Albedo : 0.29
- Bowen Ratio : 0.925
- Roughness Length : 0.0725

It was assumed that emissions from the poultry houses were constant throughout the year and that all sheds were operational. This is a worse case assumption, emissions of PM₁₀ increase during the rearing cycle that can take between 35-60 days. Between rearing cycles there is a period when the sheds are cleaned and remain empty before a new cycle begins. However, the assumptions made should allow a reasonable comparison to be made between concentrations at the monitoring site and those at the residential property on the poultry farm.

4.7.2 Results from Dispersion Modelling

The model has been used to predict the annual average and the 90.4th percentile of daily means in the area. The results have presented as contour plots showing lines of constant concentrations to demonstrate the likely differences in concentrations in the area.

The results are shown in Figures 8 and 9.



Figure 9 Annual Average PM₁₀ Concentrations predicted near to Lost Lands Farm

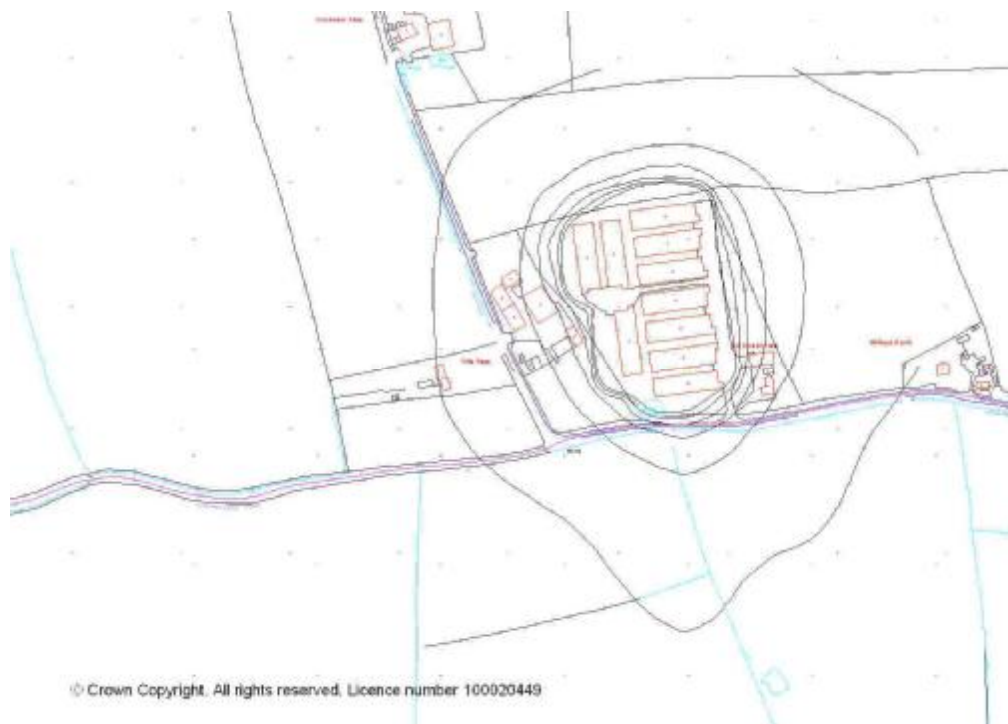


Figure 10 **90.4th Percentile of Daily Mean PM₁₀ Concentrations, Lost Lands Farm**

These results show that the concentrations at the monitoring site compared with those at the farm are comparable, there may be some difference but the actual magnitude of these will be very dependant on the dispersion model set-up. However, given that the predicted differences appear to be small and that there is considerable headroom before the objective would be exceeded it is considered unlikely that the objectives would be exceeded at this property and hence an AQMA is not required.

4.7.3 Potential for Exceedances around other Poultry Farm Operations

The ten poultry sheds at Lost Lands Farm result in a very large capacity operation concentrated in a single area, 250,000 being a very substantial operation in comparison to most poultry farms. However, the concentrations of PM₁₀ monitored relatively close by have been well within the annual average objective and appear to be very likely to meet the objective based on daily means. Any potential exceedance near a poultry farm is therefore likely to be associated with the daily mean objective. The potential for this to be exceeded would depend on the size of the sheds and the methods used for ventilation.

Given the size of the poultry farm examined in this study and the proximity of the nearest residential property it is considered very unlikely that an exceedance of the objective values is likely around any operational poultry site except in very exceptional circumstances where the background concentrations were considerably higher and there was another significant source of PM₁₀ nearby.

5 Summary and Conclusions

Earlier screening assessments carried out on behalf of South Norfolk Council identified that the emissions of fine particulate matter (PM₁₀) from poultry rearing sheds required a more detailed study because there was a risk of exceeding the relevant air quality objectives. Further assessment has therefore been carried out using a staged approach, firstly a more detailed modelling study was carried out. This study used information obtained from the Environment Agency on the likely scale of PM₁₀ emissions from poultry farming to calculate the scale of emissions from typical poultry rearing farms in South Norfolk. This emission information was then subsequently used in a dispersion modelling exercise to predict concentrations of PM₁₀ around various sizes of farm. The results of this modelling study confirmed that there was a risk of an exceedance of the objectives but that the available emissions information was very limited.

Given these conclusions the study moved onto its second stage where monitoring of the concentrations of PM₁₀ was carried out next to an operational poultry farm. This monitoring study was intended to identify whether concentrations of PM₁₀ were likely to exceed the objective values and, if so, the likely extent of the problem around these types of operations.

Monitoring equipment was therefore installed at Frith Farm which is next to a large poultry rearing facility containing up to 250,000 birds. Two types of monitoring equipment were used, a Partisol type monitor that measures gravimetric concentrations of PM₁₀ for each 24 hour period and a TEOM instrument that measures on a continuous basis but requires correction to gravimetric units for comparison with the objective values. This monitoring continued until nearly 7 months data had been collected.

The results from the monitoring show that it is unlikely that the air quality objectives will be exceeded. Average concentrations recorded at the site during the 7 months of monitoring were less than 50% of the objective value. Only 6 exceedances of the 50µg/m³ objective were observed compared with the 35 that are allowable. Even allowing for the 7 month duration of the monitoring programme it is unlikely that the daily mean objective would be exceeded.

The monitoring study has been complemented by a short dispersion modelling study that examined the relative differences in predicted concentrations at the monitoring site and a property nearest to the poultry farm. The results from this modelling indicate that concentrations at the property are likely to be similar to those measured at the monitoring site and hence an exceedance of the air quality objectives is not likely. It is therefore concluded that an Air Quality Management Area is not required for the Frith Farm site. Given that the poultry farm examined is a very large facility and the residential property is very close to the sheds it is considered unlikely that emissions from poultry farms would result in an exceedance of the air quality objectives unless background concentrations were very high or there were other significant sources of PM₁₀ in the area.