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Review of Air Quality Impacts Resulting from Particle Emissions from Poultry Farms

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1 Introduction

Particulate matter (PM) is generally categorised on the basis of the size of the particles (for example PM_{10} are particles with a median aerodynamic diameter of less than 10 µm). Particulate matter comprises primary particles emitted directly into the atmosphere and secondary particles formed by chemical reactions in the air.

Both short-term and long-term exposure to ambient levels of particles is associated with respiratory and cardiovascular illness and mortality, as well as other ill-health effects. The associations are believed to be causal. PM_{10} roughly equates to the mass of particles less than 10 micrometres in diameter that are likely to be inhaled into the thoracic region of the respiratory tract.

Data from the most recent National Atmospheric Emissions Inventory (NAEI)[1] suggests that poultry farming contributes approximately 7.1% to total primary PM_{10} emissions within the UK. As the UK poultry industry is dominated by very large scale units[2], there is therefore concern that particle emissions from poultry farms could lead locally to exceedences of national Air Quality Strategy objectives for PM_{10}, particularly where large poultry units are present close to locations of relevant exposure.

Poultry farms were introduced into the review and assessment process by LAQM.TG(09)[3] because "*a small number of local authorities have identified potential exceedences of the PM_{10} objectives associated with emissions from poultry farms*", albeit very localised. However, whilst screening criteria were introduced, the guidance contained within LAQM.TG(09) on assessing, and more specifically modelling, the air quality impact of PM emissions from poultry farms is limited, such that the Detailed Assessments of poultry farms carried out to date have been based on ambient PM_{10} monitoring, which can be both time consuming and relatively expensive.

The purpose of this study was therefore to review the suitability of the screening criteria within LAQM.TG(09) and to develop a suitable assessment methodology which local authorities could use to further assess or screen the impact of particulate matter emissions from poultry farms on air quality, potentially minimising the requirement for local authorities to proceed to a Detailed Assessment, and/or undertake ambient monitoring. This work has been undertaken by AECOM as part of the Local Air Quality Management (LAQM) Lot 1 Helpdesk Contract.

The objectives of the study were as follows:

- To review the evidence on which the existing screening criteria for the assessment of poultry farms are based;
- To review further evidence on the impacts of poultry farms on PM_{10} concentrations, provided by additional monitoring studies (including those funded by Defra); and
- To make recommendations for updated guidance to local authorities, based on the results of these additional studies.

1.1 PM_{10} Criteria

There are two Air Quality Strategy (AQS) objectives for PM_{10} against which ambient concentrations are compared. The first relates to long-term (annual mean) concentrations, and the other to short-term (24-hour or daily mean) concentrations. The PM_{10} objectives set in the Air Quality Strategy (which apply in England, Wales and Northern Ireland) are the same as limit values set by the European Union (EU), although it should be noted that the EU limit values are mandatory, whereas the AQS objectives are targets. Both have been incorporated into Statutory Instruments. The air quality objectives for PM_{10} which apply in England, Wales and Northern Ireland are:

- 50 µg/m^3 for a 24-hour mean, not to be exceeded more than 35 times a year; and
- 40 µg/m^3 for the annual mean.

The Air Quality Regulations make clear that likely exceedences of the objectives should be assessed in relation to "*the quality of the air at locations which are situated outside of buildings or other natural or man-made structures, above or below ground, and where members of the public are regularly present*". Air quality objectives therefore only apply where members of the public are likely to be regularly present and are likely to be exposed for a period of time appropriate to the averaging period of the objective. These locations are termed relevant exposure.

Experience suggests that the daily mean objective is harder to achieve than the annual mean objective in England, Wales and Northern Ireland.

The following air quality objectives apply in Scotland, which are considerably more stringent than those described above for England, Wales and Northern Ireland:

- 50 µg/m^3 for a 24-hour mean, not to be exceeded more than 7 times a year; and
- 18 µg/m^3 for the annual mean.

The annual mean objectives for Scotland is more difficult to achieve that the 24-hour mean objective.

2 Current Screening Criteria

2.1 Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) Regulation

In England, Wales and Northern Ireland, poultry farms with a capacity greater than 40,000 birds (including chickens, layers, pullets, turkeys, ducks and guinea fowl) are permitted by the EA under the Environmental Permitting Regulations (EPR). In Scotland, intensive agriculture sites are permitted by SEPA under the Pollution Prevention and Control (PPC) Regulations 2000 as amended.

Local authorities are therefore advised within LAQM.TG(09) to always ensure that their local EA/SEPA officer is aware that a particular farm had been identified in their Updating and Screening Assessment (USA) as a potential issue. The EA/SEPA however has not issued any guidance on how to assess dust emissions from poultry farms; instead EA/SEPA guidance has focussed on the sources of PM from poultry farms and measures to minimise these PM emissions.

The EPR implement the Integrated Pollution Prevention and Control (IPPC) Directive in England and Wales and came into force on 6th April 2008. The IPPC Directive requires that the Best Available Techniques (BAT) are used. Guidance has been issued by the EA on dust control emissions for poultry farms which shows that mitigation is an important factor in determining emissions. When making an application for a permit to the EA, the costs and benefits of a range of options should be compared to show that an applicant's proposals represent BAT. In Scotland, SEPA's Standard Farming Installation Rules attempt to minimise emissions from poultry units for the varying types of housing design, housing management, diet selection, production cycles etc.

If an applicant proposes to use the measures which are expressed as BAT within the relevant sector guidance note[4], options would not need to be compared. In order to assist this process, a BAT Reference Document (BREF) for Intensive Rearing of Poultry and Pigs has been produced by the European IPPC Bureau. This is currently being reviewed, and the updated version is expected in early 2013. BAT must be achieved within 4 years of the issue of the Sector BREF.

For bespoke permits, the EA/SEPA expects all new plant and livestock housing to be designed and built to the required standards. Where regulatory controls are being applied to existing plant, the EA/SEPA expects plant to be upgraded to meet the standards where necessary, with the EA/SEPA setting improvement conditions with a timescale. This would occur, for example, where a farm currently below the threshold expands above the threshold and would have a mix of existing and new buildings.

2.2 Local Air Quality Management Technical Guidance

LAQM.TG(09) introduced screening criteria in order to consider poultry farms during the Updating and Screening Assessment (USA) process. This was because "*a small number of local authorities have identified potential exceedences of the PM_{10} objectives associated with emissions from poultry farms*". The authorities where potential exceedences were identified were South Norfolk Council and Derbyshire Dales District Council[5]; the results of the monitoring surveys are provided in full in Section 6.

The screening criteria in LAQM.TG(09) were derived based on experience from studies carried out by the Environment Agency (EA), Department for Environment Northern Ireland (DoENI) and a local authority, and are reproduced below:

"*1. Identify any farms housing in excess of* *400,000 birds if mechanically ventilated.*

200,000 birds if naturally ventilated.

100,000 birds for any turkey unit.

2. *Establish whether there is relevant exposure within 100 m of the poultry units. Relevant exposure will include residential properties that form part of the farm itself.*"

If both these criteria are met, a Detailed Assessment for PM_{10} is required.

LAQM.TG(09) goes on to state:

"*Detailed Assessments for poultry farms are likely to be based on both monitoring and modelling studies. In many cases a suitable monitoring programme will need to be established to determine the impact of these sources*"

and

"*Quantifying the PM_{10} emissions arising from a poultry farm is not straightforward. Where authorities need to quantify these emissions for input to a dispersion model, they are advised to contact the relevant regulatory authority and/or the Local Authority Air Quality Support Helpdesk*".

2.2.1 Origin of LAQM.TG(09) Screening Criteria

The screening criteria were developed based on the limited monitoring data available at the time (i.e. prior to 2009), taking into account the size and type of installation and the proximity of residential exposure, in order to identify those local authorities where particulate emissions from poultry farms could potentially be significant. The intention being that those locations of greatest concern would subsequently be investigated in more detail to obtain more information[19].

2.2.2 More Recent Guidance

Since LAQM.TG(09) was a published, a Frequently Asked Question (FAQ)[6] was published on the Defra LAQM website, which is reproduced below:

"***I have identified the need to undertake a Detailed Assessment for Poultry Farms. Is there any guidance on how to do this?***

A number of local authorities have completed their Updating and Screening Assessments and have identified poultry farms that meet the criteria (as set out in the Technical Guidance (LAQM.TG(09)) that would require proceeding to a Detailed Assessment.

It is recognised that the screening criteria in TG(09) have been based on limited data, and it was stated that further information would be provided as and when new information became available. To assist this process, three local authorities in England have been awarded Air Quality Grant funding in order to carry out studies at the poultry farms they have identified, in order to assess both the local risk of exceedences of the air quality objectives, and to provide additional information to verify, or amend if necessary, the current screening criteria.

Until this assessment work is completed, there is no requirement for local authorities to move forward to a Detailed Assessment at this time. Where local circumstances (such as a history of nuisance complaints related to the farm in question) suggest that it would be preferable to proceed to a Detailed Assessment as soon as possible, authorities are advised to contact the Review and Assessment Helpdesk in order to ensure that any work carried out is in line with best practice.

Where the outcome of the Updating and Screening Assessment has identified a need for a Detailed Assessment for one or more poultry farms, then the Review and Assessment Helpdesk will have been in contact to obtain further information on their location(s). If authorities in this situation have not been contacted they should get in touch with the Helpdesk at the earliest opportunity.

As these processes are likely to be permitted by the Environment Agency, local authorities should always ensure that their local EA officer is aware that the farm has been identified in their USA as a potential issue."

The three local authorities referred to above which received Air Quality Grant funding were:

- South Holland District Council;
- New Forest District Council; and
- Aylesbury Vale District Council (this study however was not undertaken).

2.2.3 Farms which Exceed LAQM.TG(09) Screening Criteria

Defra has provided a list of local authorities, shown in Table 1, that have identified poultry farms in excess of the screening criteria within their USAs.

Table 1: List of Local Authorities with Poultry Farms in Excess of LAQM.TG(09) Criteria

Local Authority	Turkeys	Chickens	Mechanical Ventilation?	Nearest Receptor
South Holland District Council	145,000	-	-	40m
	145,000	-	-	15m
New Forest District Council	-	322,875	Yes	30m
	-	285,000	Yes	10m
North Dorset District Council	-	418,000	No	70m
Hambleton District Council	199,688	-	-	<100m
	-	421,725	Yes	<100m
Broadland District Council	>100,000	-	-	<100m
Clackmannanshire Council	-	1,200,000	Unknown	20m
Breckland Council	106,000	-	-	78m
Cheshire East Council	-	500,000	Yes	80m
West Lothian Council	-	1,300,000	Unknown	40m

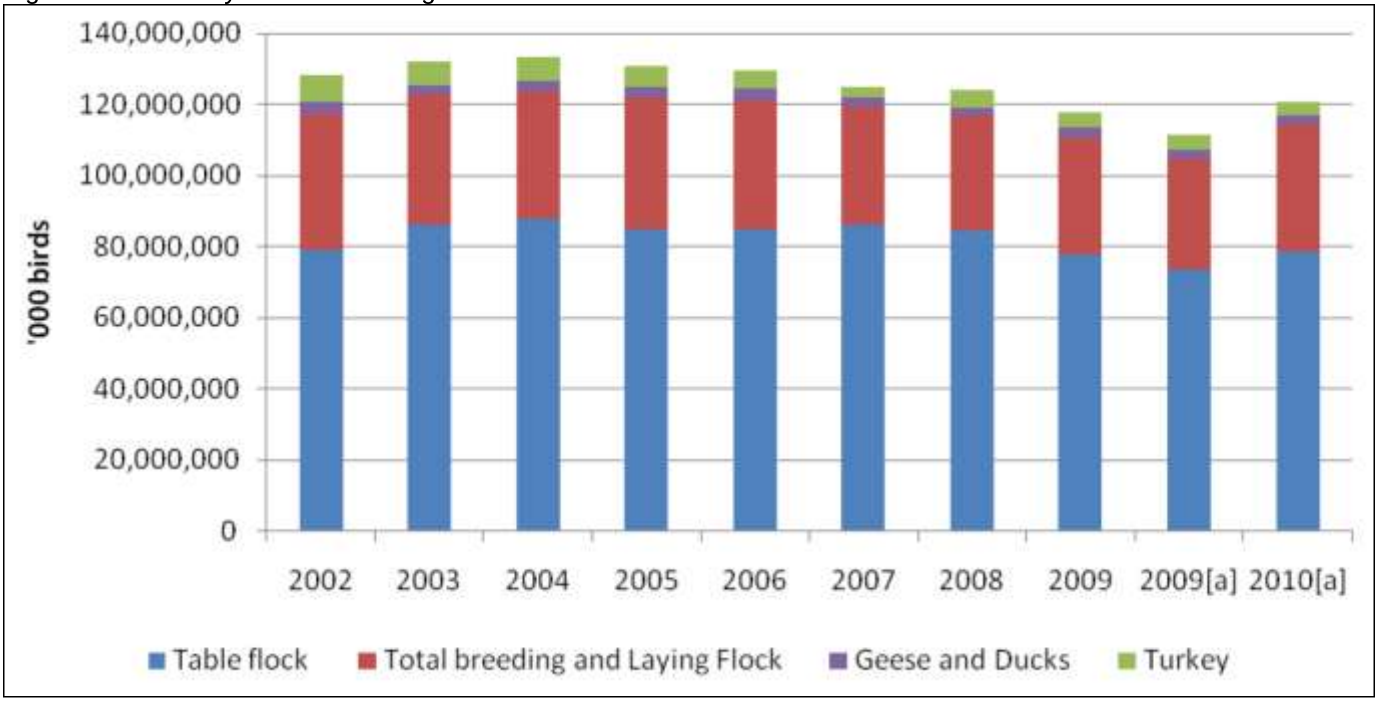
3 Summary of UK Poultry Industry

The UK poultry industry predominantly consists of broilers (i.e. chickens raised for meat production), layers (i.e. chickens raised for egg production), geese, ducks and turkeys. Further explanations of some of the terminology used in this report relating to the poultry farming industry can be found in Appendix C.

3.1 Poultry Farming in England

At June 2010, the total number of birds in production in England was 125.7 million, which comprised 63% broilers, 29% breeders and layers and 8% other poultry (ducks, geese, turkeys & other poultry)[2]. The composition of the English poultry industry is illustrated graphically in Figure 1.

Figure 1: Poultry Numbers in England at June 2002 - 2010



SOURCE: Defra (2010) June Survey of Agriculture and Horticulture

[a] June 2009 figures were revised on 16 September 2010 for two reasons. Firstly, the new methodology for 2010 employed thresholds to exclude holdings with very low activity, so revised 2009 figures were required to permit like-for-like comparison between 2009 and 2010. Secondly, the census exercise included a register cleaning exercise to enable the removal of inactive holdings from the register.

In 2009 there were 1,060 commercial broiler holdings operating in England, with the average number of birds per holding being approximately 69,500. The number of holdings and populations of laying fowl in 2009, by housing type, are shown in Table 2.

Table 2: Number of Holdings and Populations of Laying Birds, by Housing Type in 2009

Farm Type	Number of Birds	Number of Holdings	Average Number of Birds
Laying Bird - Cages	10,242,461	3,037	3,373
Laying Birds - Free Range	7,685,534	14,523	529
Laying Birds - Barn	889,963	3,364	265
Growing Pullets	5,942,435	2,056	2,890

These data demonstrate that in terms of bird numbers, the English poultry industry is dominated by broilers. Furthermore, as there are significantly fewer broiler farms in England than layer farms, this results in broiler farms housing, on average, a significantly greater number of birds.

3.2 Poultry Farming in Scotland

In June 2010 the total poultry population in Scotland was 14.59 million. The vast majority of these birds were broilers and other table birds e.g. turkeys (60%), followed by pullets and hens in the laying flock (25%). Fowls for breeding accounted for 8%, whilst pullets being reared for laying made up 6%. Other poultry made up just under 0.5% of the total[7].

3.3 Poultry Farming in Wales

In June 2010 the total poultry population in Wales was 7.6 million, spread over a total of 284 holdings[8].

3.4 Poultry Farming in Northern Ireland

A breakdown of the poultry population in Northern Ireland in 2010, taken from the Agricultural Census in Northern Ireland[9], is shown in Table 3.

Table 3: Poultry Numbers in Northern Ireland, 2010

Layers	Growing Pullets	Breeding Flock	Table Birds	
			Broilers	Other Poultry
2,099	1,017	1,078	11,915	421

4 Particulate Emissions from Poultry Farms

4.1 Poultry Housing and Ventilation

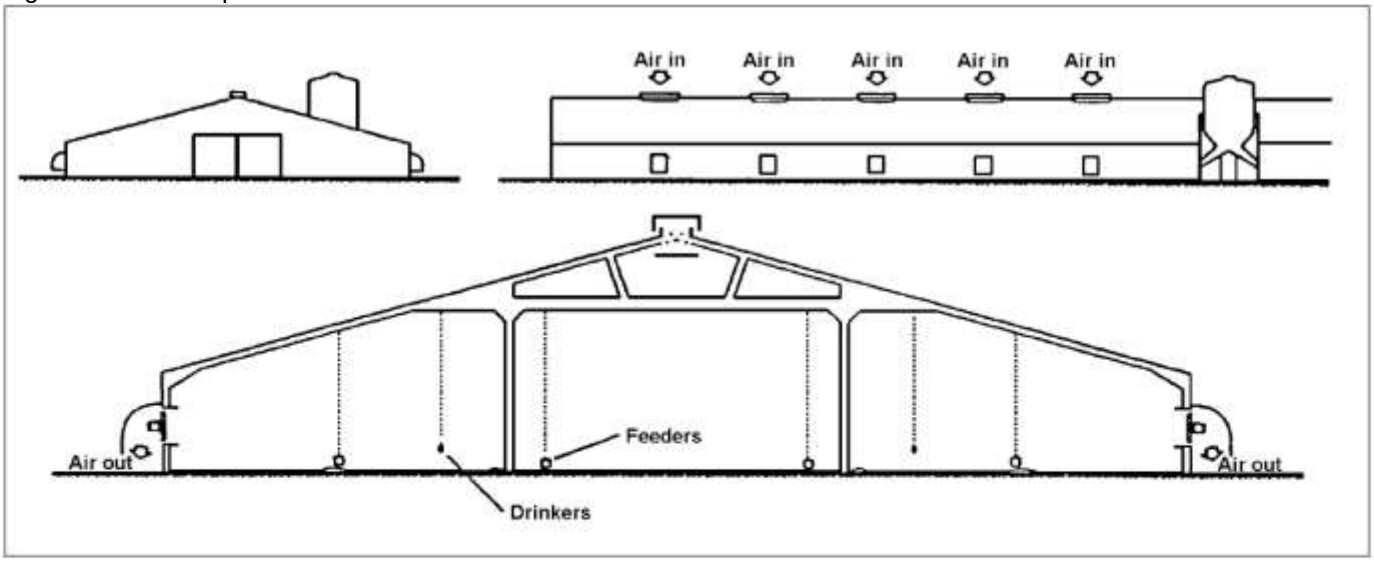
Birds used for meat production, e.g. broilers, turkeys and ducks, are commonly housed in litter-covered floor systems. Birds for egg production are housed in more varied systems such as part-littered / part-slatted floors (sometimes multi-tiered) or in tiered-cage or colony systems. Cage systems can themselves be subdivided into deep-pit houses that store droppings beneath the bird living quarters, or belt-clean houses that remove droppings from the house either direct to fields or to covered storage facilities.

All these houses must be ventilated to remove waste gases and to ensure fresh air for the birds, as well as to control internal temperatures. For litter floor systems, there is a legal remit to maintain dry, friable litter[10] to, for example, reduce contact dermatitis[11] and to promote natural behaviours. Ventilation systems achieve this by removing moisture from houses.

Ventilation can be provided by powered or natural systems. Fans can be placed in the roof or the sidewalls of buildings, mostly extracting from buildings, but occasionally designed to blow into buildings under pressure. The different types of air circulation system within a poultry house are designed for the maintenance of bird welfare as an overriding factor, and until recently within the UK, very little consideration had been given to designs specifically incorporating dust reduction techniques.

The Intensive Rearing of Poultry and Pigs (ILF) BREF (Best Available Techniques reference document)[12] suggests that in the UK, approximately 40 % of broiler houses have the ventilation on the roof, another 50 % have reverse-flow ventilation (i.e. fans mounted in the side-wall and inlets in the roof (see Figure 2)) and 10 % have cross-flow / tunnel ventilation (i.e. fans and inlets on opposite sides of the house).

Figure 2: Example of Schematic Cross-section of Broiler House with Reverse Flow Ventilation



SOURCE: Silsoe Research Institute (1997).

4.2 Sources of Particulate Emissions from Poultry Farms

In terms of the sources of particulate matter within poultry farms, the EA states that *"dust from poultry houses mainly originates from feathers, skin particles and used litter, and to a lesser extent from feed, bedding, micro-organisms and fungi"*[13]. The EMEP/CORINAIR Emission Inventory Guidebook[14] on the other hand states the following with regard to primary particulate emissions from ventilated animal housing systems:

"*There are several sources of the enrichment of airborne particulate matter within livestock buildings. The feed itself and the feeding process may contribute to 80 to 90 % of the total dust generation. Bedding materials like straw or wood shavings can also have extraordinary effects on the particle concentration in the livestock air. Depending on the type and the amount of litter and its spreading, its contribution can be between 55 and 68 % of the total airborne particulates observed. The animal skin, fleece or plumage of housed animals and their faeces and urine cause dust emissions which may contribute up to 12 % of the total dust amounts released within livestock buildings. To a lesser extent, particles may originate from friction against floors, walls and other structural elements and from the air intake into the house.*

Animal activity may also lead to re-suspension into the livestock house atmosphere of dust already settled (re-entrainment)."

It should be noted that the EMEP/CORINAIR guidance relates to animal housing in general (i.e. it also includes cattle and pigs etc.), whereas the guidance from the EA relates specifically to poultry farms and is UK specific. The above statements suggest that the relative contribution of different sources to total particulate emissions from poultry farms is far from certain.

4.3 Factors Affecting Particulate Emissions from Poultry Farms

Factors affecting particulate emissions from poultry farms include type of bird, type of housing system, type of ventilation, bedding materials, litter condition, air temperature, humidity, flow rate, type and amount of feed and animal activity level[15].

In addition, the EMEP/EEA emission inventory guidebook[16] suggests that mass flows of emitted particulates from poultry farms are governed by the following parameters (examples in brackets), thus causing uncertainties in terms of predicted emissions[17]:

- physical density and particle size distribution of livestock related particulate matter;
- type of housed animals;
- type of feeding system (dry vs. wet, automatic vs. manual, feed storage conditions);
- type of floor (partly or fully slatted);
- the use of bedding material (straw or wood shavings);
- the manure system (liquid vs. solid, removal and storage, manure drying on conveyor belts);
- animal activity (species, circadian rhythms, young vs adult animals, caged vs aviary systems);
- ventilation rate (summer vs. winter, forced vs naturally ventilated);
- geometry and positions of inlets and outlets (re-entrainment of deposited particles caused by turbulence above the surfaces within the building);
- indoor climate in the building (temperature and relative humidity);
- the time-period of housing (whole year vs. seasonal housing);
- the management (all-in and all-out systems, with periods of empty livestock building due to cleaning and disinfection procedures vs. continuously rearing systems);
- secondary sources due to farmers' activities (tractors, walking through the building to check on livestock);
- cleaning practices (forced air vs. vacuum).

4.3.1 Feed

One component of livestock-derived particulate matter is feed[18]. Particulate matter concentrations within poultry units may be increased if the form of the feed is initially dusty, as with some non-pelleted feeds for laying hens. Broiler feed is less dusty as it is moulded into pellet form that contains a higher level of fat.

The equipment in which feed is administered can also increase the amount of airborne particulates. Li et al[19] found that dust increased by 150% when both meal and pellet feeds were administered by a "screw" auger system rather than by hand. Automatic feeders can generate particulates when feed is being dropped into the troughs, especially if the feed is as a meal or if the pellets are badly formed. Feeders that "over administer" are also a cause of particulate formation, for example in broiler housing[20]. The spilled feed is gradually crushed on the floor into smaller particles which become airborne due to bird activity.

4.3.2 Bedding

A second source of poultry-related particulate emissions is the re-suspension of bedding material. Takai et al. and Ellen et al.[21] found that particulate emissions were four to five times higher from houses using bedding rather than cages with wire floors. However, many egg producers in the UK (and throughout Europe) are moving towards littered systems for poultry on the grounds of animal welfare. Various bedding materials are used, such as sawdust, flax, wheat, barley or rye straw paper, clay pellets, peat and wood shavings.

Deep bedding systems as used in turkey and duck production have been shown to contribute fewer particles to the environment than shallow bedding systems[22]. Deep litter is thought to "sediment" the particles to the lower layers of the bedding where the increased humidity traps the particles and helps to bind it in place, reducing particle concentrations by approximately 50%. However, deep litter is not deemed suitable for broilers, as a study has shown that litter deeper than 5 cm resulted in a significantly ($P < 0.05$) higher prevalence of foot-pad dermatitis[23] in the flock. As bedding materials break down to a dry friable litter, particle production increases. As the straw degenerates with time, fine straw particles become airborne and elevate indoor particulate matter levels. Even with "pre-packed, dust-extracted" bedding materials, particle levels will be low at first but will increase due to activity occurring in the litter.

5 Assessment Methodology

The following assessment methodology has been employed within this study:

- Information pertinent to this study was extracted from reports on PM_{10} monitoring in the vicinity of poultry farms;
- If required, additional information was subsequently requested from the relevant monitoring body, including raw monitoring datasets;
- Where possible, the incremental contribution of the poultry farms to monitored local PM_{10} concentrations was estimated, by subtracting appropriate background concentrations;
- A literature review was undertaken in order to determine published PM_{10} emission factors associated with poultry farms, and the factors affecting emission rates;
- The information derived from the monitoring studies was used to develop a method for assessing the potential impact of poultry farms on short-term PM_{10} concentrations.

5.1 Review of Monitoring Studies

Initially, the following reports on PM_{10} monitoring in the vicinity of poultry farms were reviewed, in order to extract information pertinent to this study.

Studies prior to publication of LAQM.TG(09):

- South Norfolk District Council's PM_{10} Detailed Assessment (2006)[24];
- Study of Ambient Air Quality At Newborough (2003)[25];
- Isle of Anglesey County Council's Air Quality Progress Reports (2003/04 – 2006/07)[26];
- Report on PM_{10} Sampling Equipment at Poultry Farm, Eglish (2005)[27];
- Report on PM_{10} Sampling Equipment at Poultry Farm, Augher (2007)[28];
- Report on PM_{10} Sampling Equipment at Poultry Farm, Brantry (2008)[29];

Studies following publication of LAQM.TG(09):

- South Holland District Council's PM_{10} Detailed Assessment (2011)[30];
- New Forest District Council's PM_{10} Detailed Assessment (2011)[31];
- North Dorset Council's PM_{10} Detailed Assessment (2010)[32];
- Derbyshire Dales District Council's PM_{10} Detailed Assessment (2009)[33]; and
- Study of Ambient Air Quality at Cubley (2011)[34].

Where information of importance to this study was not provided within the reports described above, the relevant organisation was contacted in an attempt to obtain the relevant information. This included requesting raw monitoring data. In a number of cases, information of relevance to this study was not recorded during the monitoring study, including in some instances the number of birds on the farm at the time of the monitoring, and the type and location of ventilation.

5.2 Estimating Poultry Farm Contribution

Using the available raw monitoring data obtained, the contribution of each farm to monitored PM_{10} concentrations was estimated, by subtracting representative background levels from monitored daily mean concentrations. The monitoring sites from which background concentrations were obtained for each farm are described in Appendix B, together with the data used to estimate the average and maximum incremental contribution of the relevant poultry farm to measured PM_{10} concentrations.

5.2.1 Limitations

It should be noted that in most cases, the process described above was complicated by the scarcity of background monitoring data local to the farms in question, and in particular by the lack of rural background sites which monitor PM_{10}. This has resulted in some of the background data used being sourced from monitoring sites some distance from the farms in question, and in some cases from urban background sites. The approximate distance of the background site used to determine the incremental contribution for each of the farms has therefore been provided.

Ideally, hourly or even 15-minute data would have been used when subtracting the background contribution from monitored PM_{10} concentrations, given that PM_{10} emissions of short duration, or brief periods when the analyser was downwind of the poultry farm, may be obscured by comparing PM_{10} concentrations averaged over a 24-hour period. However, for the purposes of consistency and in some cases because of limited data availability, daily mean PM_{10} concentrations have been considered in all cases.

The effect of the limitations described above is illustrated quite clearly by those days where assumed daily mean PM_{10} background concentrations exceeded monitored PM_{10} concentrations at the farm in question. On these occasions, the incremental contribution of the farm to monitored PM_{10} concentrations was assumed to be zero.

It should also be noted that this process assumes that the estimated incremental contribution is due solely to the poultry unit under investigation, whereas PM_{10} concentrations could be affected by other sources or other farm-related activities. This is evidenced by the comments associated with the daily mean concentrations recorded at the Augher and Brantry farms, where a number of days where PM_{10} concentrations exceeded 50 µg/m^3 were attributed to other activities and not the chicken-rearing process.

6 Monitoring Studies

The results from a number of monitoring studies undertaken in the vicinity of poultry farms are summarised in this section; however, it is important to note that there was no co-ordinated approach to these studies. This has resulted in different monitoring methods being employed over varying time periods. Moreover, none of the studies were conducted in Scotland. It should also be noted that the majority of this monitoring was undertaken at locations representative of relevant exposure or at locations where it was practical for the monitor to be located. The concentrations recorded during these studies were therefore not necessarily worst-case; for example, concentrations downwind and closer to the poultry units may well have been higher than those measured at the position of the analyser.

A number of different analysers were employed in the studies, brief descriptions of which are provided below:

- Beta Attenuation Monitor (BAM) - this device draws sampled air at a constant flow rate through a section of paper tape, on which particles from the air are collected. At the beginning and end of the sampling period (one to 24 hours), transmission of beta particles through the tape (from a source inside the instrument) is measured. The difference between the two measurements, caused by the particulate matter collected on the tape, is used to determine the concentration. A correction factor is subsequently applied in order for results to be reference equivalent.
- Tapered Element Oscillating Microbalance (TEOM) - In the TEOM, sampled ambient air passes at a constant flow rate through a filter, attached to a vibrating hollow tapered element. As particulate matter is collected on the filter, the frequency of vibration of the element decreases. The mass of particulate matter collected over a period of 15 minutes or one hour can thus be calculated. The TEOM uses a heated sample inlet to prevent moisture from contaminating the filter: studies in recent years have shown that this results in the loss of volatile and semi-volatile components of PM_{10}, and until recently Defra advised applying a default correction factor (1.3) to take account of this. This advice has now been superseded; the current advice is to use the King's College London Volatile Correction Model (VCM) where possible. No correction is required where a TEOM is retrofitted with a Filter Dynamics Measurement System (FDMS).
- OSIRIS – this is a portable instrument which uses a light scattering method to measure the ambient concentration of fine particles. LAQM.TG(09) states that the instrument is considered suitable for use in Review and Assessment, but not for a Detailed Assessment.
- Partisol - this sampler draws a measured volume of air through a filter, which is weighed before and after the sampling period (this is usually 24 hours). Automated samplers are capable of collecting up to sixteen consecutive 24-hour PM_{10} filter samples.

The First Daughter Directive 1999/30/EC sets limit values for particles within the PM_{10} fraction, based on measurements made using the reference method EN12341 – a filter-based gravimetric measurement method. Partisols and TEOMs retrofitted with FDMS can be considered equivalent to the reference method. Results from TEOMs and BAMs must be corrected to be reference equivalent through the applications of correction factors.

All the data presented henceforth in this report have therefore been converted to reference equivalent. OSIRIS data cannot be considered reference equivalent, even with the application of a correction factor. The OSIRIS data presented in this report should therefore be considered indicative.

6.1 Monitoring Studies Undertaken for LAQM Purposes or by the EA

A number of monitoring studies have been undertaken in the vicinity of UK poultry farms on behalf of local authorities under the Local Air Quality Management (LAQM) process or by the EA under the EPR regime. The location, monitoring method and duration of each of these monitoring studies, together with the distance and direction of the poultry units relative to the analyser, are given in Table 4 and Table 5. Further details of each of these studies are provided in Appendix A.

Table 4: Location, Method and Duration of Monitoring Undertaken near poultry Farms for LAQM

Monitoring Body	Location	Monitoring Method	Date of Monitoring	Duration (Days)	Approximate Direction of Poultry Units Relative to Analyser	Approximate Distance from Analyser to Closest Poultry Unit
South Holland DC	Fleet Fen Farm	BAM[a]	11/09/10 to 16/03/11	190	220 - 340°	50 m
New Forest DC	Sway	BAM[b]	09/06/10 to 09/11/10	154	70 - 140° & 200 – 250°	120 m
Northern Ireland Environment Agency (NIEA)	Augher	TEOM[c]	26/10/05 to 15/12/06	403	260 - 320	90 m
	Eglish	TEOM[c]	21/11/04 to 19/08/05	243	230 - 10°	40 m
	Brantry	TEOM[d]	28/12/06 to 03/02/08	403	340 - 70°	15 m
North Dorset DC	Blandford Forum	OSIRIS[e]	08/09/09 to 10/12/09	94	30 - 70°	70 m
South Norfolk Council	Great Moulton	Partisol[e]	23/07/05 to 22/12/05 & 08/04/06 to 28/06/06	235	20 - 110°	60 m
Isle of Anglesey County Council	Pen Lon	OSIRIS[c]	04/03/04 to 31/12/04	303	130 - 225°	60 m
			01/01/05 to 31/12/05	365		
			01/01/06 to 31/12/06	365		
			01/01/07 to 09/04/07	99		

[a] These data were corrected by dividing by 1.273 in accordance with the UK equivalence study report published in 2006[35].
[b] These data were corrected by dividing by 1.21 in accordance with the UK equivalence study report published in 2006[13].
[c] These data were multiplied by 1.3 to estimate gravimetric equivalent concentrations.
[d] These data were multiplied by 1.3 to estimate gravimetric equivalent concentrations until 31/07/07 when an FDMS was fitted, after which no correction was applied.
[e] No gravimetric correction was applied to these data.

Table 5: Location, Method and Duration of Monitoring Undertaken near Poultry Farms by the EA

Location	Monitoring Method	Date of Monitoring	Duration (Days)	Approximate Direction of Poultry Unit Relative to Analyser	Approximate Distance from Analyser to Closest Farm building
Pen Lôn	TEOM[a]	19/06/03 to 15/10/03	119	130 - 225°	30 m
Cubley	TEOM[b]	23/10/08 to 05/05/09	195	130 - 260°	10 m
		30/11/10 to 31/01/11	62	100 - 260°	10 m

[a] These data were multiplied by 1.3 to estimate gravimetric equivalent concentrations.
[b] These data were corrected using the King's College Volatile Correction Model (VCM).

The type and capacity of each of the poultry farms are summarised in Table 6.

Table 6: Poultry Farm Type and Capacity at which LAQM or EA Monitoring was undertaken

Monitoring Body	Location	Farm Type	Capacity (Birds)	Mechanically Ventilated?	Location of Vents
South Holland DC	Fleet Fen Farm	Turkey	145,000[a]	No	Side mounted
New Forest DC	Sway	Broilers	72,000 and 173,500	Yes	Roof Mounted[b]
NIEA	Augher	Broilers	241,000[c]	Yes	Side Mounted
	Eglish	Broilers	195,000[c]	Yes	Side Mounted
	Brantry	Broilers	119,000[c]	Yes	Side / Roof Mounted
North Dorset DC	Blandford Forum	Layers	418,000	Yes	Not recorded
South Norfolk Council	Great Moulton	Broilers	250,000	Not recorded	Side Mounted[d]
EA	Cubley	Broilers	69,900	Yes	Roof Mounted
Anglesey / EA	Pen Lôn	Broilers	190,000	Yes	Roof Mounted

[a] During the monitoring period a maximum of 89,961 birds were being reared.
[b] Assumed based on aerial photos.
[c] Average number during survey period.
[d] Based on assumption made within Detailed Assessment report.

Table 6 indicates that the majority of monitoring studies have been undertaken in the vicinity of broiler farms of varying capacity, however in a number of cases, information relevant to this study was not reported. The height at which the particulates were released is not known; the vents were variously roof or side-wall mounted.

The results of each of the monitoring studies are summarised in Table 7.

Table 7: Summary of Results of LAQM and EA Monitoring near UK Poultry Farms

Location	Year	Approximate Duration	Mean PM_{10} Concentration ($\mu g/m^3$)	Daily Mean PM_{10}			Data Capture for Monitoring Period
				No. of Days > 50 $\mu g/m^3$		Maximum	
				Measured	Estimated No. per Year[f]		
Fleet Fen Farm	2010 / 2011	6 months	23.2[a]	8	21[b]	58.7	99%
Sway	2010	6 months	24.1	1	2	55	94%
Augher	2005 / 2006	14 months	22.0	18[c]	17	79	96%
Eglish	2004 / 2005	8 months	20.6	4	6	53.7	93%
Brantry	2006 / 2008	14 months	16.0	6[d]	6	72	90%
Blandford Forum	2009	3 months	18.3	0	0	45	95%
Great Moulton	2005 / 2006	8 months	21.7	6	12	87.1	63%
Anglesey	2003	7 months	20.1	4	6	61.2	85%
	2004	12 months	19.8	9	9	79.9	70%
	2005	12 months	19.6	6	6	76.4	88%
	2006	12 months	23.9	12	12	106.6[g]	90%
	2007	3 months	28.4	6	24	110.9	100%
Cubley	2008 / 2009	6 months	25.4	13	**37**[e]	81.5	67%
	2010 / 2011	2 months	19.3	0	0	41.8	91%
Pen Lôn	2003	4 months	25.2	4	12	76.9	96%

[a] Theoretical maximum based on mean incremental contribution of the poultry farm and monitored annual mean background concentrations in 2010.
[b] Maximum possible number of exceedences based on maximum contribution of poultry farm to daily mean PM_{10} concentrations and monitored background concentrations in 2010.
[c] Of which 12 were attributed to the chicken rearing process. The daily average exceedences on the other six days coincided with the laying of stones around the chicken houses and with agricultural work carried out in neighbouring fields.
[d] Of which 5 were attributed to the chicken rearing process. The daily average exceedence on one day coincided with the burning of bushes in neighbouring fields.
[e] Whist the number of exceedences predicted over a year is only slightly above the permitted 35, it is considered that the monitoring was undertaken during the winter and spring seasons which is not when emissions are likely to be highest. Emissions are likely to increase during warmer months when poultry shed temperatures are higher, birds are more active and more ventilation is required. Consequently the factoring up of the number of exceedences over the 130 days of the monitoring period when data was captured is likely to be a conservative prediction.
[f] Scaled to annual number of exceedences based on duration of monitoring, unless otherwise stated.
[g] should be noted that 9 out of the 12 exceedences occurred during September 2006. As it appeared that this was due to a local source, the Local Authority was prompted to contact the Poultry Farm. Upon investigation, it was evident that these elevated levels may have been due to large fans at the end of the sheds, which are used during extreme heat, being inadvertently left on.

6.1.1 Discussion of Results

The results in Table 7 indicate that annual mean PM_{10} concentrations in the vicinity of the poultry farms at which monitoring has been undertaken are well within the annual mean AQS objective (applicable in England, Wales and Northern Ireland) at locations of relevant exposure where monitoring was feasible, reflecting the rural location of these sites. However, the number of days on which PM_{10} concentrations exceeded 50 µg/m^3, and the maximum daily mean PM_{10} concentrations measured during the surveys, suggest that poultry farms have the potential to significantly affect short-term PM_{10} concentrations. Only one site (Cubley) was estimated to have exceeded the PM_{10} AQS objective for short-term concentrations (applicable in England, Wales and Northern Ireland), in 2008 / 2009. However, it should be noted that a more recent survey at this farm undertaken in 2010 / 2011 indicates that the daily mean PM_{10} objective would now be met. This more recent monitoring followed the implementation of a number of measures aimed at reducing PM_{10} emissions from the farm[36]. The EA has undertaken additional monitoring at this farm, completed at the end of September 2011[37].

A comparison of the monitoring results in Table 7 with the screening criteria in LAQM.TG(09) is provided in Table 8.

Table 8: Comparison of Monitoring Results to LAQM.TG(09) Screening Criteria

Farm	Bird Type	Number of Birds	Mech. Ventilation ?	Distance of Monitor to Nearest Poultry Unit	Are TG(09) Screening Criteria Exceeded?	Monitored Exceedence of Daily Mean Objective for England, Wales and NI?	Monitored Exceedence of Annual Mean Objective for England, Wales and NI?
Fleet Fen	Turkeys	89,961	No	50 m	No	No	No
Sway	Broilers	72,000 and 173,500	Yes	120 m	No	No	No
Augher	Broilers	241,000	Yes	90 m	No	No	No
Eglish	Broilers	195,000	Yes	40 m	No	No	No
Brantry	Broilers	119,000	Yes	15 m	No	No	No
Blandford Forum	Layers	418,000	Yes	70 m	Yes	No	No
Great Moulton	Broilers	250,000	Not recorded	60 m	Potentially	No	No
Cubley	Broilers	69,900	Yes	10 m	No	No[a]	No
Pen Lôn	Broilers	250,000	Yes	30 m	No	No	No

[a] Based on 2010 / 2011 Survey Results

Table 8 indicates that the screening criteria in LAQM.TG(09) to proceed to a Detailed Assessment were met at one, or potentially two, of the poultry farms at which monitoring has been undertaken. As no exceedences of the annual mean or daily mean AQS PM_{10} objectives were recorded (with the exception of the measured concentrations at Cubley prior to the implementation of dust mitigation measures) this indicates that exceedences of the air quality objectives (applicable in England, Wales and Northern Ireland) are unlikely in the vicinity of farms which do not meet the screening criteria in LAQM.TG(09). Therefore, the LAQM.TG(09) screening criteria have been validated by the monitoring studies. However, as monitoring has only been undertaken at one farm which meets the screening criteria, which consisted of an OSIRIS for three months, it is not possible to determine whether AQS objective exceedences are likely when the screening criteria are exceeded, particularly as the results from the 2008 / 2009 survey at Cubley illustrate that exceedences can potentially occur in very close proximity to relatively small farms in the absence of appropriate mitigation. This suggests that a revision or update of the screening criteria is necessary, as the LAQM.TG(09) screening criteria may oblige a Detailed Assessment to be conducted when in fact the AQS objectives are unlikely to be breached.

6.2 Estimated Contribution of Poultry Farms to Daily Mean PM_{10} concentrations

In order to determine the contribution of each of the poultry farms to the monitored concentrations shown in Table 7, the contribution of background sources to monitored ambient concentrations must be removed. The only study to do this specifically was the study undertaken on behalf of South Norfolk DC. Therefore, where possible, raw monitoring data have been obtained for each of the monitoring studies described in Table 7 in order that background concentrations can be removed from monitored PM_{10} concentrations, and thus the incremental contribution from the poultry farm can be estimated. This process is described in more detail in Appendix B, with the results summarised in Table 9.

It should be noted that an incremental contribution from the monitoring study in Sway was not calculated, given that the analyser was located between two separate poultry farms and in close proximity to a road and a waste transfer station; it was considered that the contribution of either poultry farm could not be determined with a satisfactory degree of confidence. Furthermore, incremental contributions from the data obtained using OSIRIS analysers have not been calculated given that results from these analysers can only be considered indicative.

Table 9: Estimated Incremental Contribution of Poultry Farms

Location	**Estimated Incremental Contribution to Annual Mean PM_{10} Concentration ($\mu g/m^3$)**	**Estimated Maximum Contribution to Daily Mean PM_{10} Concentration ($\mu g/m^3$)**
Fleet Fen Farm[a]	6.2	21
Augher[b]	10.9	65
Eglish[c]	10.2	45
Brantry[d]	4.1	48
Pen Lon (EA Study)[e]	4.8	50
Cubley (2010 / 2011)[f]	8.0	28
Great Moulton[g]	6.9	33

[a] During monitoring period there was a maximum of 89,961 turkeys at the farm. Analyser located approx. 50 m from the nearest poultry unit.
[b] During monitoring period there was an average of 241,000 broilers at the farm. Analyser located approx. 90 m from the nearest poultry unit.
[c] During monitoring period there was a maximum of 115,200 broilers at the farm. Analyser located approx. 40 m from the nearest poultry unit.
[d] During monitoring period there was an average of 119,000 broilers at the farm. Analyser located approx. 15 m from the nearest poultry unit.
[e] During monitoring period there was a maximum of 190,000 broilers at the farm. Analyser located approx. 60 m from the nearest poultry unit.
[f] During monitoring period there was a maximum of 69,900 broilers at the farm. Analyser located approx. 10 m from the nearest poultry unit.
[g] During monitoring period there was a maximum of 250,000 broilers at the farm. Analyser located approx. 60 m from the nearest poultry unit.

6.2.1 Discussion of Results

Table 9 indicates that poultry farms can make a significant incremental contribution to both annual and daily mean PM_{10} concentrations. It should be noted that the concentrations shown in Table 9 are at varying distances from the poultry units in question and were not necessarily measured at locations downwind of the farm. This means that the estimated annual mean incremental contributions shown above are not necessarily worst-case or directly comparable.

The maximum estimated contribution to daily mean PM_{10} concentrations is considered more likely to be representative of the worst-case contribution of the poultry farm at the relevant distance, given that this is likely to have occurred when the analyser was downwind of the poultry farm. This is evidenced by the maximum monitored concentrations at Pen Lon, South Holland, Brantry and Cubley, which all occurred when the analyser was downwind of the poultry farm. This parameter is therefore considered a more reliable measure of the potential worst-case contribution of poultry farms than the annual mean PM_{10} contributions shown in Table 9.

It should be noted that, as is evidenced in Figures 16, 17 and 18 in Appendix B, PM_{10} concentrations in the vicinity of poultry farms can be significantly affected by other activities at the farm, in particular the removal of birds from the poultry units. This process only occurs on a relatively infrequent basis at the end of each rearing cycle (i.e. approximately every 40 days), meaning that these maximum contributions are likely to occur infrequently.

6.3 Defra Funded Research Project

A recent research project undertaken on behalf of Defra[38] aimed to characterise poultry dust, quantify emission levels, review emission abatement techniques and assess the potential impact on human health. During the study a total of eight poultry farms (two broiler, two caged layer, two free range layer and two broiler farms fitted with abatement techniques) were visited twice (summer and winter).

The monitoring results shown in Table 10 were obtained using static Partisol samplers located ‘upwind’ and at various distances ‘downwind’ of the poultry farms, although these measurements were made over a period of only two to three days during each farm visit. The report therefore states that “*the particulates data in this study provide a snapshot of conditions in the vicinity of poultry houses and should be viewed in this context*”. This statement is reinforced by the high variability of these measurements, illustrated by the high standard deviation of the measurements.

The monitoring undertaken at the broiler farms was timed so that the broilers were between 25-30 days old at the start of the monitoring, so that the birds were large enough to be a representative sample, whilst avoiding thinning events (usually at 32 days of age), i.e. when dust concentrations were expected to be at or near peak.

Whilst the results in Table 10 cannot be compared directly to AQS objectives because of the limited duration of the monitoring, comparison of the measurements upwind and downwind of the respective farms suggests that PM_{10} concentrations were elevated in the vicinity of the poultry farms, particularly up to 50 metres downwind. To illustrate this point, the contribution of the different poultry farms to monitored daily mean PM_{10} concentrations have been estimated by subtracting the daily mean PM_{10} concentrations measured upwind of each farm, from those measured downwind, as shown in Table 11.

Table 11 suggests that the contribution of poultry farms to daily mean PM_{10} can be significant, particularly in close proximity to the farms. The majority of the measured concentrations in Table 11 are likely to be worst-case, given that the monitoring was undertaken downwind of the farms and during the periods when dust emissions were expected to be highest. The negative values in Table 11 highlight the difficulty in separating the contribution from the poultry farms from total monitored concentrations, and suggest that either that the ‘downwind’ monitors were not always downwind of the farms and/or that some of the upwind monitors were affected by emissions from other sources.

Table 10: Results of Defra Funded Research Project

Farm Type	Farm ID	Season	Light / Dark	Daily Mean PM_{10} Concentrations determined by Partisol (µg/m^3)				
				Upwind	**Downwind Up to**			
				50m	**50m**	**100m**	**150m**	**400m**
Broiler	B	Winter	Light	18	24	27	24	23
			Dark	54 (4)	59 (18)	51 (36)	60 (10)	60 (4)
		Summer	Light	18 (7)	23 (2)	38 (13)	-	-
			Dark	37 (28)	149 (146)	11 (20)	-	-
	F	Winter	Light	15 (12)	22 (4)	18 (2)	10	9
			Dark	14 (0)	40 (20)	19 (9)	15	19
		Summer	Light	22 (15)	91 (76)	26	16	40
			Dark	31 (33)	84 (72)	35	39	35
Caged Layer	A	Winter	Light	30 (7)	24 (10)	24 (11)	28 (6)	26 (14)
			Dark	34 (25)	33 (18)	32 (22)	26 (11)	31 (4)
		Summer	Light	-	-	-	-	-
			Dark	-	-	-	-	-
	D	Winter	Light	14 (8)	25 (8)	24 (8)	43 (12)	
			Dark	10 (14)	23 (3)	19 (2)	58 (56)	
		Summer	Light	4 (8)	26 (3)	-	-	22 (1)
			Dark	1 (1)	17 (9)	-	-	18 (6)
Free Range Layer	C	Winter	Light	19 (0)	31 (6)	27 (3)	26 (0)	22 (2)
			Dark	31 (23)	29 (13)	32 (13)	29 (11)	28 (9)
		Summer	Light	24 (10)	36 (7)	9 (23)		
			Dark	27 (7)	26 (3)	26 (4)		
	E	Winter	Light	44 (60)	18 (60)	19 (3)	16 (3)	15 (1)
			Dark	12	30	14 (3)	12 (1)	11 (1)
		Summer	Light	19 (2)	48 (2)	36 (8)	27 (6)	-
			Dark	14 (0)	18 (0)	15 (1)	17 (3)	

NOTES: Standard Deviation in Brackets.
Light and Dark refers to the light (day time) and dark (night time) periods for the birds. These periods were not necessarily during the actual day and night times. Lighting is controlled within poultry farms to control the birds sleep patterns, n turn influencing feed consumption and therefore growth rates.

Table 11: Estimated Poultry Farm Contribution from Results of Defra Poultry Farm Monitoring Study

Farm Type	Farm ID	Season	Light / Dark	Estimated Contribution of Poultry farm to Daily Mean PM_{10} Concentrations determined by Partisol ($\mu g/m^3$) Downwind Up to			
				50m	100m	150m	400m
Broiler	B	Winter	Light	6	9	6	5
			Dark	5	-3	6	6
		Summer	Light	5	20		
			Dark	112	-26		
	F	Winter	Light	7	3	-5	-6
			Dark	26	5	1	5
		Summer	Light	69	4	-6	18
			Dark	53	4	8	4
Cage	A	Winter	Light	-6	-6	-2	-4
			Dark	-1	-2	-8	-3
		Summer	Light	0	0	0	0
			Dark	0	0	0	0
	D	Winter	Light	11	10	29	
			Dark	13	9	48	
		Summer	Light	22	-4	-4	18
			Dark	16	-1	-1	17
Free Range	C	Winter	Light	12	8	7	3
			Dark	-2	1	-2	-3
		Summer	Light	12	-15		
			Dark	-1	-1		
	E	Winter	Light	-26	-25	-28	-29
			Dark	18	2	0	-1
		Summer	Light	29	17	8	
			Dark	4	1	3	

NOTES: Light and Dark refers to the light (day time) and dark (night time) periods for the birds. These periods were not necessarily during the actual day and night times. Lighting is controlled within poultry farms to control the birds sleep patterns, in turn influencing feed consumption and therefore growth rates.

7 Emission Factors

Numerous emission factors have been proposed (or derived) in an attempt to estimate PM_{10} emissions from poultry farms. A selection of these emissions factors are summarised below including those emission factors derived from monitoring studies, and those proposed for emission inventory purposes.

7.1 Emission Factors Derived from Monitoring Studies

A number of monitoring studies have been undertaken in an attempt to determine particulate emission rates from poultry farms. For these emissions data to be of practical use, the emission rates have been reported as a rate of emission per livestock unit (LU), thereby enabling the emissions from one poultry operation to be correlated to another poultry operation. Roumeliotis and Van Heyst undertook a review of emission factors in 2008[39] which was summarised in a recent study undertaken on behalf of Defra, along with the results of the Defra-funded research project itself. These emission factors are reproduced in Table 12.

Table 12: Compilation of Emission Factors from Literature (modified from Roumeliotis and Van Heyst)

Type of Operation	Country	Study	Ventilation Type	House and manure system	PM_{10} Emission Factor (mg/LU hr)[a]
Broiler	Canada (Ontario)	Roumeliotis and Van Heyst[40]	Mechanically ventilated	Litter floor	241.25 ± 7.9
	The Netherlands	Van der Hoek[41]	Various	Litter floor	79.2
	United States (TX)	Lacey et al.[42]	Tunnel-ventilated	Litter floor	537.5
	United Kingdom	Defra Research Project	Mechanically ventilated	Litter floor	565 ± 357
Layer	The Netherlands	Van der Hoek	Various	Cages, belt system	9.6
	The Netherlands	Van der Hoek	Various	Litter floor	108.4
	United States (IN)	Jacobson et al.[43]	Mechanically ventilated	High-rise	83.4 – 416.8
	United States (IN)	Lim et al.[44]	Mechanically ventilated	Battery cage	625 ± 142
	United Kingdom	Defra Research Project	Mechanically ventilated	Battery cage	176 ± 136
	United Kingdom	Defra Research Project	Mechanically ventilated	Free Range Litter Floor	1450 ± 994
Turkey	The Netherlands	Van der Hoek	Various	Litter floor	387.7

[a] One Livestock Unit (LU) represents a live weight of 500 kg. Considering the length of a production cycle, the average weight of a broiler (including both male and female statistics) is 1.56 kg per bird[6]. The average weight of a layer is 1.58 kg per bird[6]. During the growth cycle, the average weight of a turkey is 6.3 kg assuming an equal ratio of male and female birds[6].

Roumeliotis and Van Heyst concluded that "*PM emission factors developed form the various studies were inconsistent, even within a particular sector of poultry production*" and that "*it is likely that the local climate of a poultry house as well as its type of ventilation and manure management could account for this variability*". They also suggested that government agencies "*must ensure that the current inventories are based on scientifically defensible measurements ... that are typical; of the practices in their jurisdictions.*"

The Defra-funded research project final report concluded that "*for the broiler farms, the PM_{10} EF data from Lacey et al. agrees well with our measurements, whilst those of Roumeliotis and Van Heyst are 50% lower, but still with one standard deviation of our collective measurements*". However, one of the recommendations of the report was that "*given the high variability of the measured $PM_{2.5}$ and PM_{10} emission factors in this work, a further program of measurements (less detailed) should be undertaken to improve the certainty of the data.*"

7.2 Emission Factors from Emissions Inventories

A number of emission factors are used to represents PM_{10} emissions from poultry farms within national and European emission inventories. Those from the National Atmospheric Emissions Inventory (NAEI), EMEP/EEA and the EA[45] are shown in Table 13, in addition to those derived during the Defra-funded research project.

Table 13: Estimates of PM_{10} Emission factors within Emission Inventories

<table>
<tr><th>Animal Category</th><th>Housing Type</th><th>NAEI PM_{10} Emission Factor kg animal^{-1} a^{-1}</th><th>EMEP/EEA 2009 PM_{10} Emission Factor kg animal^{-1} a^{-1}</th><th>EA PM_{10} Emission Factor[a] kg animal^{-1} a^{-1}</th><th>Defra Funded Research Project PM_{10} Emission Factor kg animal^{-1} a^{-1}</th></tr>
<tr><td rowspan="2">Laying Hens</td><td>Cages</td><td rowspan="2">0.0195</td><td>0.017</td><td>0.05</td><td rowspan="2">0.006</td></tr>
<tr><td>Perchery</td><td>0.084</td><td>0.1</td></tr>
<tr><td>Broilers</td><td>Solid</td><td>0.0588</td><td>0.052</td><td>0.1</td><td>0.012</td></tr>
<tr><td>Turkeys (male)</td><td>-</td><td>-</td><td rowspan="3">0.032</td><td>0.9</td><td>-</td></tr>
<tr><td>Turkeys (female)</td><td>-</td><td>-</td><td>0.5</td><td>-</td></tr>
<tr><td>Ducks</td><td>-</td><td>-</td><td>0.2</td><td>-</td></tr>
<tr><td>Pullets</td><td>-</td><td>-</td><td>-</td><td>0.1</td><td>-</td></tr>
</table>

[a] It should be noted that these EFs are based on the number of animal places, rather than the number of animals, although for the purposes of this comparison the emission factors are assumed to be equivalent.

Table 13 indicates that the emission factors from the NAEI and EMEP/EEA are comparable, but that the emission factors proposed by the EA are somewhat higher. In comparison, the emission factors derived during the Defra-funded poultry farm study (which are shown in Table 13 in comparable units) are an order of magnitude lower than those proposed within any of the emissions inventories.

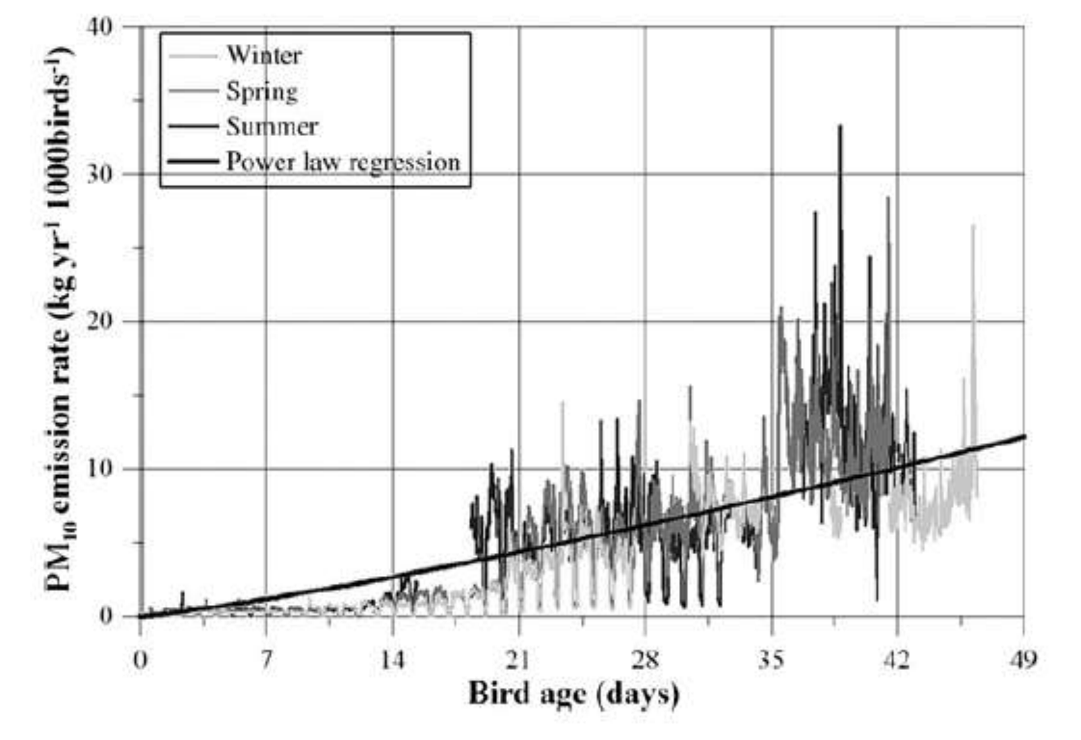
7.3 Variation in Emission Rates over Time

The emission factors above are average emission rates and therefore assume a constant rate of emission. However, the Defra-funded research project concluded that with a few exceptions, the poultry sheds produced more particles during light periods than during dark periods (due to reduced bird activity during dark periods). Slight increases in summer emission factors compared to winter time were also observed, with the exception of one farm, which displayed higher emission factors in winter. This was considered generally consistent with increased ventilation rates in summer.

Roumeliotis and Van Heyst also observed diurnal variation in particulate matter concentrations, related to the decreased activity level of broilers during periods of darkness. They also concluded that indoor PM_{10} concentrations for winter and summer production cycles follow a similar pattern for the first 14 days of the production cycle; after this time, the patterns in seasonal PM concentrations varied significantly. Overall, measured indoor particulate matter levels were highest in the wintertime, when the amount of air exhausted by the ventilation fans was lowest. The average summertime indoor PM_{10} concentration was approximately 46% of the average wintertime concentration. For the spring production cycle, the PM_{10} levels were also reduced to approximately 80% of the wintertime levels. As indoor PM_{10} concentrations were reduced during the spring and summer periods due to increased ventilation, this indicates that a greater amount of particulate matter was extracted from the poultry units during these periods, suggesting emission rates from the farm would be higher during these periods. Roumeliotis and Van Heyst also demonstrated that PM_{10} emission rates increased significantly with bird age, due to the rise in

PM_{10} generation as the birds increase in size, as well as when the house ventilation rate increases to maintain internal temperatures, as illustrated in Figure 3. Roumelitois and Van Heyst noted that summer emissions were occasionally higher at the end of the production cycle due to extreme ventilation rates. It is unclear whether the estimated emission rates at the end of the rearing cycles shown below, included periods when birds were being removed from the farm.

Figure 3: Real-time Emission Rates for Three Seasons (Roumeliotis and Van Heyst (2007))



In view of the number of variables in estimating particulate emission rates from poultry units, and the uncertainties in the published emission factors even when allowing for seasonality, diurnal variation, bird type/age, housing, ventilation system etc, it is not possible at this point in time to make recommendations on atmospheric dispersion modelling as a tool for assessing the air quality impact of poultry farms.

8 Discussion and Conclusions

The objectives of this study were as follows:

- To review the evidence on which the existing screening criteria for the assessment of poultry farms were based;
- To assess further evidence on the impacts of poultry farms on PM_{10} concentrations provided by additional monitoring studies; and
- To make recommendations for updated guidance to local authorities (where possible and necessary), based on the results of these additional studies.

8.1 Origins and Suitability of LAQM.TG(09) Screening Criteria

The poultry farm screening criteria in LAQM.TG(09) were developed based on the limited monitoring data available at the time. It is clear that they comprised a rough estimate based on the size and type of installation and the proximity of residential exposure, which was proposed to identify those local authorities where particulate emissions from poultry farms had the potential to be significant. The intention was that those locations of greatest concern would subsequently be investigated in more detail to obtain more information.

The results of the monitoring studies undertaken in the proximity of poultry farms to date suggest that exceedences of the air quality objectives for PM_{10} (applicable in England, Wales and Northern Ireland) are unlikely at farms below the screening criteria in LAQM.TG(09). Therefore, the LAQM.TG(09) criteria have been validated.

However, the LAQM.TG(09) criteria may be too conservative, indicating the need for a Detailed Assessment when in fact the likelihood of breaches of the AQS objectives is very low. For this reason, a revision/update to the screening criteria would be helpful for LAQM, based on the new data provided by the more recent monitoring studies.

The monitoring results also suggests that exceedences of the AQS objectives for PM_{10} which are applicable in Scotland are possible. However, it should be noted that none of the monitoring studies were undertaken in Scotland and therefore the results obtained may not be representative of conditions in Scotland.

8.2 Further Evidence Provided By Recent Studies

The LAQM monitoring studies undertaken to date, and those undertaken by the EA, demonstrate that exceedences of the annual mean AQS objective for PM_{10} (applicable in England, Wales and Northern Ireland) in the vicinity of poultry farms are unlikely, but that poultry farms have the potential to have a significant effect on daily mean PM_{10} concentrations. The potential effect of poultry farms on daily mean PM_{10} concentrations has therefore been the focus of additional analysis.

Only one study (undertaken on behalf of South Holland DC), specifically estimated the contribution of the poultry farm to daily mean PM_{10} concentrations, by subtracting background measurements made elsewhere from monitored concentrations. The maximum measured incremental contribution from the farm to daily mean concentrations was subsequently used to estimate the maximum number of days > 50 ug/m^3 which could occur, based on monitored background concentrations over the course of the year. This methodology is considered to be a suitable approach to estimate the likely maximum effect of a poultry farm on daily mean PM_{10} concentrations.

The maximum incremental contribution to daily mean PM_{10} concentrations measured during each monitoring study was therefore estimated, where raw data could be obtained, by subtracting measured local background concentrations from monitored daily mean PM_{10} concentrations. An attempt has subsequently been made to infer a relationship between maximum (i.e. 100^{th} percentile) estimated daily mean PM_{10} concentrations and distance (from source to monitor), by normalising monitored concentrations against the number of birds on each farm. Figure 4 below illustrates the results of this process for the Eglish, Brantry, Pen Lon, Cubley and Great Moulton broiler farms. The results from the Augher and Fleet Fen farms are included in Figure 4 for information purposes, but have not been used to develop the inferred relationship as Augher is considered to be an outlier and Fleet Fen is a turkey farm.

Figure 4: Relationship between Maximum Estimated Incremental Contribution to Daily Mean PM_{10} and Distance

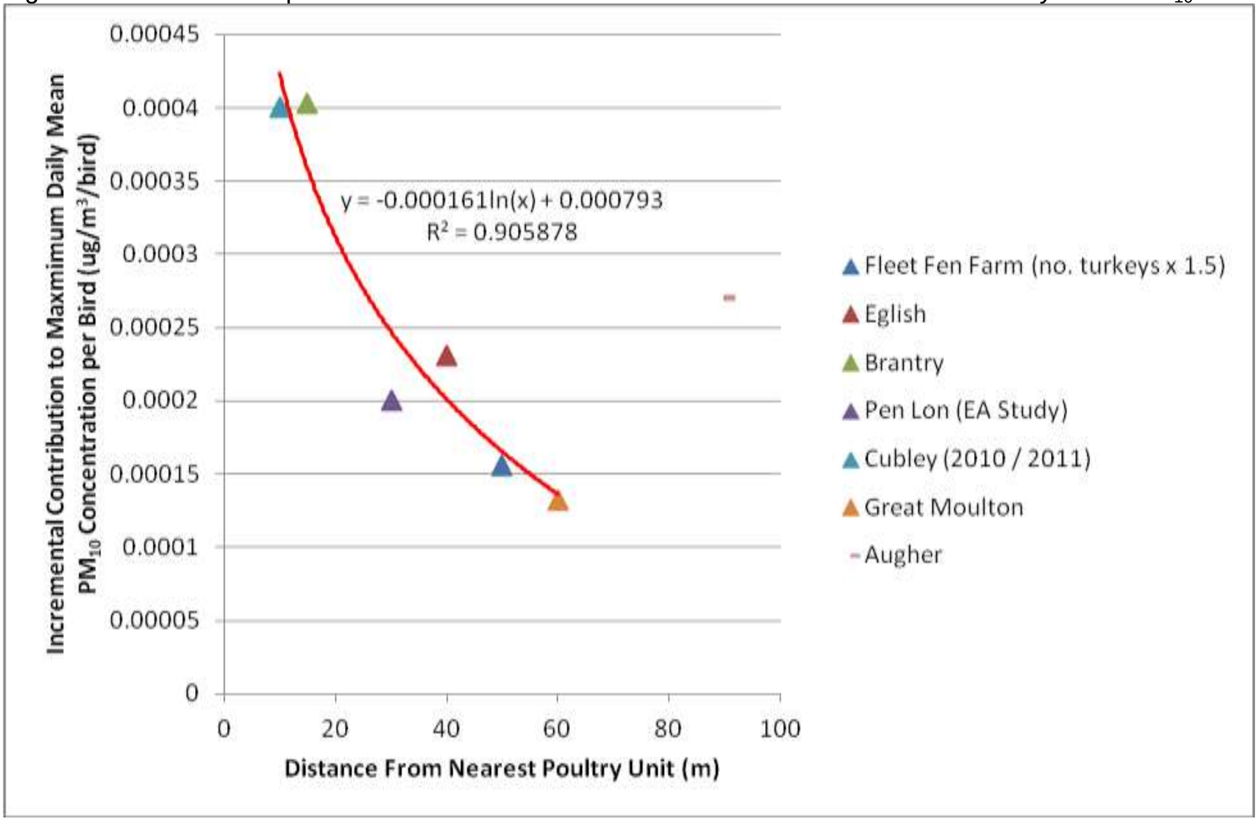


Figure 4 suggests that the maximum estimated incremental contribution to daily mean PM_{10} concentrations per bird tends to decrease with distance and that a good relationship can be fitted between the majority of data points (excluding the results at Augher). Additional monitoring data (if they can be obtained by future monitoring studies), particularly at farms in excess of the screening criteria in LAQM.TG(09) would lead to greater confidence in the trend established. As evidenced by the results at the Augher farm, there will not to be a direct correlation between maximum daily mean PM_{10} concentrations and distance in all instances. These discrepancies are thought likely to be as a result of activities and management processes employed the farms, which, as described in this report, can significantly affect PM_{10} concentrations.

Fleet Fen is a turkey farm. If the number of birds on the farm is multiplied by 1.5 to account for the turkey's larger size, the data from this farm also fit the relationship.

The relationship described above can be used to estimate the maximum (i.e. 100th percentile) incremental contribution to daily mean PM_{10} concentrations (MD) for a given number of broilers (b) at a given distance (d) using the following formula:

$$MD = (-0.000161 \ln d + 0.000793) \times b$$

For a turkey farm, the number of birds should be multiplied by 1.5, and then the relationship can be used.

The PM_{10} short-term AQS objectives are equivalent to a 98th percentile of daily mean values in Scotland and as a 90.4th percentile in England, Wales and Northern Ireland. The monitoring data were analysed to determine the ratio between the specified percentile and the maximum daily (i.e.100th percentile) increment. There was a wide variation in the ratios between the sites due to the monitors being in different orientations to the poultry shed and so would be downwind for a different proportion of time and due to the variable emissions from the shed.

The results of the analysis are shown in Table 14. The highest ratio for each percentile was selected for the data from the broiler farms which was 0.83 for the 98th percentile and 0.55 for the 90.4th percentile. These factors can be applied to the calculated maximum daily increment to get the 98th percentile or 90.4th percentile.

Table 14: Derivation of Scaling Factors from Monitoring Data

Farm	Maximum daily increment	98th percentile increment to daily mean	90.4th percentile increment to daily mean	98th percentile / maximum daily increment	90.4th percentile / maximum daily increment
Pen Lon	283	70	51	0.22	0.13
Cubley	42	34	29	0.79	0.55
Great Moulton	62	56	35	0.83	0.44
Augher	79	60	37	0.69	0.38
Brantry	72	49	31	0.52	0.29
Fleet Fen (turkey)	21	19	13	0.92	0.62

LAQM.TG(09) advises on how to add worst-case process contributions to background concentrations in order to get an estimate of total PM_{10} concentrations (source + background). For the 98th percentile concentration, the annual mean background concentrations should be doubled and the 98th percentile increment due to the poultry farm added to it. For the 90.4th percentile, the 90.4th percentile source increment should be added to the annual mean background concentration.

The ratios identified above from the broiler farms were applied with the relationship to estimate daily concentrations and the results compared with measurements in Table 15.

The predicted 98th percentile concentrations (relevant for farms in Scotland) are slightly higher than the measured values at all sites except for Augher which is an outlier. The method works well for the 98th percentile. There was some under-estimation for the 90.4th percentile concentrations (relevant for farms in England, Wales and Northern Ireland).

The ratios between percentile and maximum concentrations derived in Table 14 were slightly higher for Fleet Fen (turkey) Farm than at the broiler farms so these higher ratios were applied in Table 16.

Table 15: Comparison of Predicted and Measured Results Using Broiler Farm Ratios

Farm	No. of Birds (b)		Measured ($\mu g/m^3$)		Predicted Increment using empirical relationship ($\mu g/m^3$)			Total ($\mu g/m^3$)			
		Distance d (m)	Maximum daily increment (MD)	Background mean	Maximum daily increment (MD)	98th %	90th %	98th% Measured	98th % Predicted	90th % Measured	90th % Predicted
Gt Moulton	250	60	33	15	33	28	18	56	58	35	33
Cubley	69.9	10	28	13	30	24	16	34	50	29	29
Eglish	195	40	45	11	39	32	21	50	54	35	32
Pen Lon	190	60	50	23	25	21	14	52	67	39	37
Brantry	119	15	72	11	42	35	23	49	57	31	34
Augher	241	90	79	11	17	14	9	60	36	37	20
Fleet Fen	217.5*	50	59	18	35	29	20	52	65	35	38

*Adjusted for turkeys, MD = maximum daily increment, P=predicted, M=measured

Table 16: Comparison of Predicted and Measured Results Using Fleet Fen Farm Ratios

Farm	No. of Birds (b)		Measured (µg/m^3)		Predicted Increment (µg/m^3)			Total (µg/m^3)			
		Distance d (m)	Maximum daily increment (MD)	Background mean	Maximum daily increment (MD)	98th %	90th %	98th % Measured	98th % Predicted	90th % Measured	90th % Predicted
Gt Moulton	250	60	33	15	33	31	21	56	61	35	36
Cubley	69.9	10	28	13	30	27	18	34	53	29	31
Eglish	195	40	45	11	39	36	24	50	58	35	35
Pen Lon	190	60	50	23	25	23	16	52	69	39	39
Brantry	119	15	72	11	42	39	26	49	61	31	37
Augher	241	90	79	11	17	15	10	60	37	37	21
Fleet Fen	217.5*	50	59	18	35	33	22	52	69	35	40

*Adjusted for turkeys, MD = maximum daily increment, P=predicted, M=measured

The predicted 98th percentile concentrations are higher than the measured values at all sites except for Augher which is an outlier and higher than the values predicted using the broiler farm ratio. The predicted 90.4th percentile concentrations are higher than the measured values at all sites except for Augher which is an outlier. The higher (Fleet Fen) ratio works better for the 90.4th percentile predictions.

The scaling factors that should be used to adjust the maximum (100th percentile) daily increments are therefore 0.83 for the 98th percentile and 0.62 for the 90.4th percentile.

These empirical relationships can comprise the updated screening criteria for assessing the air quality impact of poultry farms. The results of the equations are conservative, as befits a screening tool. If the results of these new equations indicate a breach of the relevant short-term AQO for PM_{10}, then there is a need for a Detailed Assessment, which should be based on ambient monitoring. If the results of the equations indicate no breach of the relevant short-term objective for PM_{10}, then there is no need to proceed to a Detailed Assessment.

A similar empirical relationship could not be established from estimated contributions to annual mean PM_{10} concentrations (of particular importance for compliance in Scotland), as there was too much scatter in the data and no clear pattern. This may be due in part to the fact that monitoring was not undertaken downwind of the farms in all cases. This has meant that the annual mean concentrations recorded are influenced by the location of the analyser in relation to the fluctuating direction of prevailing winds, as well as distance.

8.3 Recommendations for updated Guidance

The key factors in determining PM_{10} concentrations in the vicinity of poultry farms are considered to be:

- PM_{10} emission rates from the poultry units (which depend on a number of factors including the number of birds, the type of bird, bird age, the building ventilation system employed and conditions and activities within the poultry unit);
- The distance between relevant exposure and the poultry units;
- The location of relevant exposure/monitoring relative to the poultry units, as this determines how often the farm is downwind;
- Dispersion conditions (wind speed and stability etc.); and
- Background PM_{10} concentrations.

It is likely that the information available to a local authority when carrying out an assessment of particulate emissions from poultry farms would be background concentration, the location and distance of relevant exposure in relation to the farm, and the number and type of birds at the farm. Any assessment/screening tool would therefore need to take account of these data only.

Emission factors collected as part of a literature review vary significantly, meaning that certainty in these emission factors is low. Whilst the emission factors determined during the research project undertaken on behalf of Defra could be considered of greatest relevance to this study (being UK specific and having been undertaken relatively recently), the authors of the study itself recommend that "*given the high variability of the measured $PM_{2.5}$ and PM_{10} emission factors in this work a further program of measurements (less detailed) should be undertaken to improve the certainty of the data*". In addition, the emission factors proposed for national and European emission inventory purposes (e.g. NAEI, EMEP/EEA) are an order of magnitude greater than those determined during the Defra study, suggesting that if these were used, they are likely over estimate PM_{10} emissions.

Two research projects have demonstrated that particulate matter emissions from poultry farms vary on a diurnal basis due to changes in bird activity, as well as seasonally and over the course of bird rearing cycles, due to increasing bird size and ventilation rates. Furthermore, the results of the monitoring undertaken to-date indicates that PM_{10} concentrations in the vicinity of poultry farms can increase significantly when birds are being removed from the poultry farm at the end of rearing cycles. The 'average' emission factors described in Section 7 are therefore considered unlikely to be representative of worst-case particulate emissions from poultry farms. It is during periods when these worst-case emissions occur that exceedences of daily mean PM_{10} concentrations are most likely.

Confidence in predicting daily mean PM_{10} concentrations using dispersion modelling is therefore considered relatively low given the uncertainties described above.

A relationship has been developed between the incremental contribution of broiler farms to maximum daily mean PM_{10} concentrations and distance, which can form the basis of updated guidance on the air quality assessment of poultry farms. However, additional monitoring, particularly at farms in excess of the screening criteria in LAQM.TG(09), is recommended in order to improve confidence in this relationship. Any additional monitoring should include the determination of the incremental contribution of the poultry farm to annual and daily mean PM_{10} concentrations by the subtraction of monitored background concentrations. Additional monitoring data is also required to further test the applicability of the empirical relationships to turkey and layer farms.

8.4 Conclusions

The conclusions of this report are summarised below:

- The existing screening criteria for poultry farms in LAQM.TG(09) were developed based on the limited amount of monitoring data available at the time. They were a rough estimate based on the size and type of installation and the proximity of residential exposure, derived primarily to determine those local authorities where impacts of particulate emissions from poultry farms had the potential to be most significant and therefore where additional assessment should be undertaken.
-
- The results of monitoring studies undertaken in the proximity of poultry farms suggest that the air quality strategy objectives for PM_{10} that apply in England, Wales and Northern Ireland, are unlikely to be exceeded at farms below the screening criteria in LAQM.TG(09). However, the monitoring studies also show that the existing screening criteria may be overly conservative, suggesting the need for a Detailed Assessment for certain poultry farms which would not in reality cause breaches of the AQOs for PM_{10}. Therefore, an empirical relationship has been established which provides updated/further screening of short-term PM_{10} impacts.
-
- The monitoring studies indicate that poultry farms have the potential to have a significant effect on daily mean PM_{10} concentrations, suggesting that exceedences of the AQS daily mean objective that applies in England, Wales and Northern Ireland (equivalent to a 90.4^{th} percentile), could potentially occur in close proximity to large poultry farms.
-
- The monitoring results also suggests that exceedences of the air quality objectives for PM_{10} that apply in Scotland (equivalent to a 98^{th} percentile), which are considerably more stringent than those which apply in the rest of the UK, have the potential to occur. However, none of the monitoring studies were undertaken in Scotland specifically and therefore the results obtained may not be representative of conditions in Scotland.
-
- Emission factors identified as part of a literature review vary significantly, meaning that certainty in these emission factors is low. Furthermore, it has been demonstrated that particulate emissions from poultry farms vary on a diurnal basis due to changes in bird activity, as well as seasonally and over the course of bird rearing cycles, due

to increasing bird size and ventilation rates. In addition, the results of the monitoring undertaken to date indicate that PM_{10} concentrations in the vicinity of poultry farms can increase significantly when birds are being removed from the poultry farm at the end of rearing cycles. The 'average' emission factors described in Section 7 are therefore considered unlikely to be representative of worst-case particulate emissions from poultry farms. As it is during periods when these worst-case emissions occur that exceedences of daily mean PM_{10} concentrations are most likely to be observed, this suggests that dispersion modelling of particulate emissions from poultry farms based on 'average' emission factors is unlikely to result in accurately predict maximum daily mean PM_{10} concentrations.

- The maximum incremental contribution to daily mean PM_{10} concentrations measured during each monitoring study was subsequently estimated by subtracting measured background concentrations from monitored daily mean PM_{10} concentrations. A relationship was then established, for mechanically ventilated broiler farms, between maximum (100th percentile) estimated daily mean PM_{10} concentrations and distance, by normalising maximum estimated daily mean PM_{10} concentrations against the number of broilers on each farm. The relationship derived can therefore be used to estimate the maximum incremental contribution to daily mean PM_{10} concentrations (MD) for a given number of birds(b) at a given distance (d) using the following formula:

$$MD =(-0.000161 \ln d + 0.000793) \times b$$

- It can also be applied for turkey farms if the number of birds is multiplied by 1.5 to account for their larger size. The 98th and 90.4th percentile contributions from the poultry farm should be estimated by scaling the maximum increment by factors of 0.83 and 0.62 respectively.
- This value can then be added to the annual mean background concentration for the 90.4th percentile (applicable in England, Wales and Northern Ireland), or twice the annual mean for the 98th percentile (applicable in Scotland) , to estimate the total percentile concentration. This estimate is likely to be worst-case, and so can be used as an updated screening tool.

- A similar empirical relationship could not be established from derived estimated contributions to annual mean PM_{10} concentrations; the annual mean concentrations recorded are influenced by the location of the analyser in relation to the direction of prevailing winds, as well as distance. The annual mean contributions estimated for each farm are therefore not directly comparable.

- Additional monitoring, particularly at farms in excess of the screening criteria in LAQM.TG(09), is recommended in order to test, and improve confidence in, the empirical relationship which comprises the updated screening tool. Any additional monitoring should include the determination of the incremental contribution of the poultry farm to annual and daily mean PM_{10} concentrations by the subtraction of monitored background concentrations. Additional monitoring data is also required to verify or improve similar relationships for turkey, goose and layer farms.

Appendix A: Poultry Farm Monitoring Studies

New Forest DC

AEA installed an air quality monitoring station to measure PM_{10} concentrations at a relevant location near to the two poultry farms on Pitmore Lane. The monitor was located in the garden of a residential property (Green Pastures) between Pitmore Farm, Matford Farm, and Ambervale Waste Transfer station and was approximately 100 m north-east of the poultry sheds at Pitmore Farm, 100 m north-west of the poultry sheds at Matford Farm, and 100 m south west of Ambervale Waste Transfer Station.

The monitor measured PM_{10} concentrations by beta-attenuation. The air quality objectives relate to PM_{10} concentrations measured by gravimetric device. The unheated Met-One Beta Attenuation Monitor (BAM) meets the gravimetric equivalence criteria with a correction factor for the gradient, i.e. results should be divided by a factor of 1.21 when the flow is measured at standard temperature and pressure conditions. The results reported here include the correction factor.

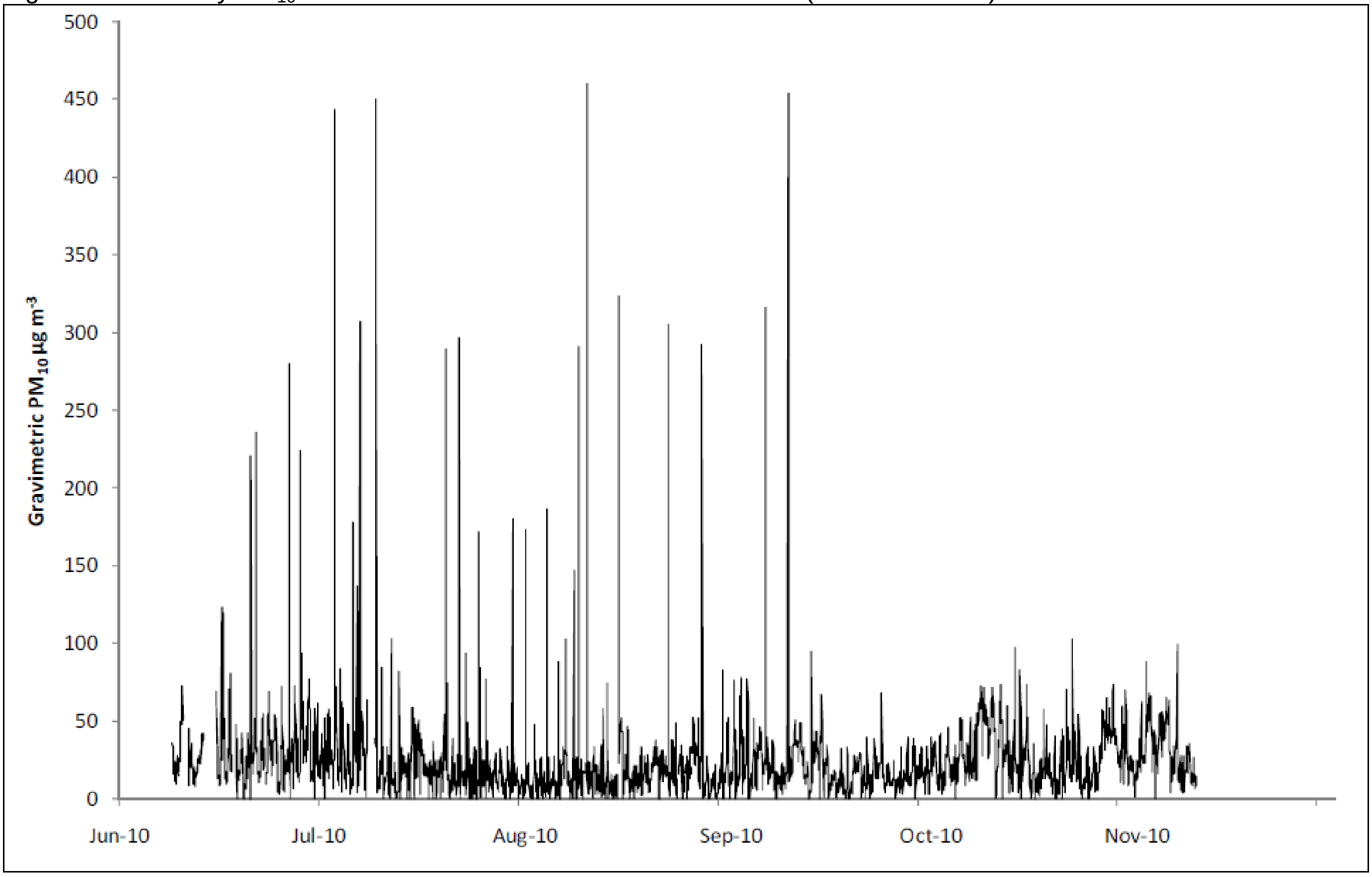
The monitor operated from 9 June 2010 to 9 November 2010. Defra's Technical Guidance recommends that ideally monitoring should be carried out for a period of at least 12 months. It recommends that where this is not possible, measurements should be carried out over the period when emissions are likely to be highest. The 5-month monitoring period includes the driest summer months and so it is expected that it covers the period when emissions are likely to be highest. The production period for broiler chickens is approximately 50 days (including the time taken to clean and restock the sheds). The monitoring period thus includes three cycles of production. Table 17 summarises the monitoring results.

Table 17: Monitoring results from the Green Pastures monitor

Statistic	PM_{10}
Maximum hourly mean	456 μg m^{-3}
Maximum daily mean	55 μg m^{-3}
Number of days when daily mean exceeded 50 μg m^{-3}	1
Average	24.1 μg m^{-3}
Data capture	94.0 %

Figure 5 shows the hourly mean concentrations (corrected BAM, gravimetric equivalent) measured throughout the period. The plot shows that relatively high hourly mean concentrations in excess of 150 μg m^{-3} were measured on several occasions throughout the summer. However, the daily mean concentration only exceeded 50 μg m^{-3} (gravimetric) on one day (8th October 2010). It is thus likely that the air quality objective of less than 35 exceedence days in a year would be met at the monitoring site. The period average concentration of 24.1 μg m^{-3} was substantially smaller than the annual mean objective of 40 μg m^{-3}. It is therefore likely that the annual mean objective would be met as the contribution from the poultry farms would be lower in the winter months.

Figure 5: Hourly PM_{10} Measurements at Green Pastures Monitor (corrected BAM)



South Norfolk DC

Monitoring was carried out at a site within Frith Farm, Frith Way, Great Moulton. There is a large poultry farm (Lostlands Farm) next to Frith Farm that has reported to the Council that up to 250,000 birds are kept on site, with 25,000 birds in ten sheds. It was considered important for the monitoring to use a method of measurement that would allow the results to be directly compared with the UK air quality strategy objective without correction. Therefore, a Partisol type monitor was installed at the monitoring site to measure 24-hour average PM_{10} 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 was visited at least every fortnight to replace the filters in the Partisol or when the site telemetry indicated a possible fault. The TEOM was set to report hourly PM_{10} average concentrations (and the results processed by TRL to provide 24 hour average concentrations). The wind speed and direction gauge recorded hourly average wind speed and direction. The Partisol monitor measured for a 24-hour average.

During the monitoring period (23 July – 22 December 2005 and 8 April – 28 June 2006), the basic results from the Partisol and TEOM monitors are shown in Table 18.

Table 18: Monitoring Results from Frith Farm

Averaging Period	Partisol (µg/m^3)	TEOM (µg/m^3)
Average Concentration	21.7	18.1
Maximum 24 Hour Average	87.1	50.3
Minimum 24 Hour Average	4.2	6.0
Number of 24 Hour Averages > 50 µg/m^3	6	1

It is known that the TEOM instrument will generally under-estimate 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 was possible to directly derive a correction factor. The results from each instrument were plotted as an X-Y graph and a linear regression undertaken. The regression shows that the TEOM results require a correction of 1.228 to account for the under-reading of the instrument. This is slightly lower than that normally observed, but most measurements of PM_{10} 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 resulted in 6 exceedences of 50 µg/m^3 during the monitoring period.

The results were also analysed to examine the influence of wind direction on the observed concentrations. The results were firstly processed to determine the average PM_{10} concentration as a function of wind direction. The measured values were sorted by wind direction into 30° sectors and the average concentration calculated. The results were further analysed by examining various percentile concentrations. If there was 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 PM_{10} would be affected by wind directions over a relatively large arc. Therefore it was not appropriate to analyse these results further by wind direction to obtain further information on the source of the particulate matter. The results are shown in Figures 6 and 7 below.

Figure 6: Pollution Rose of Average PM_{10} Concentrations

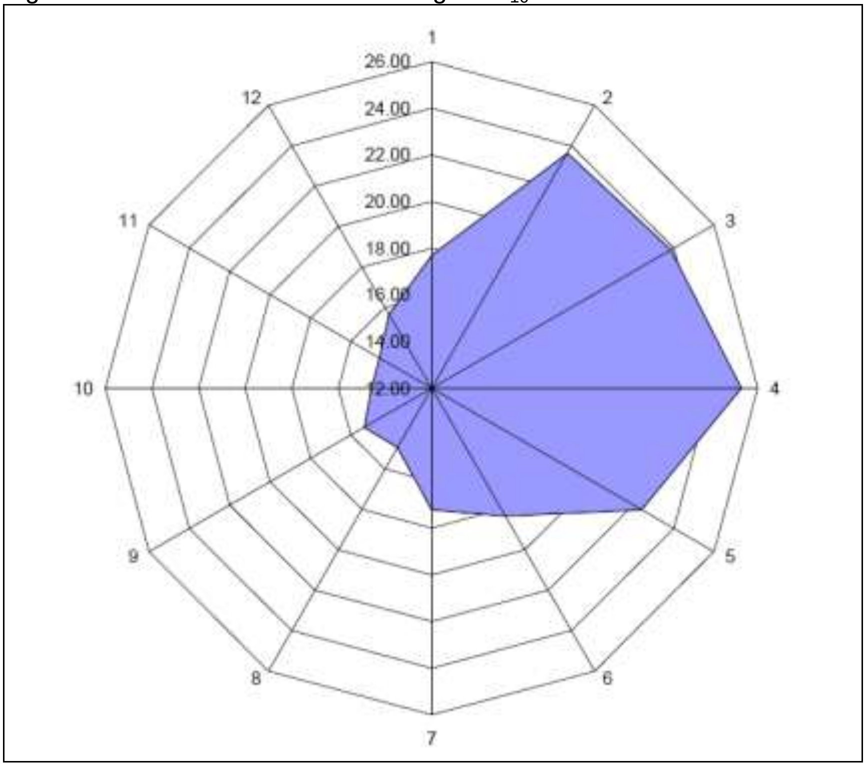
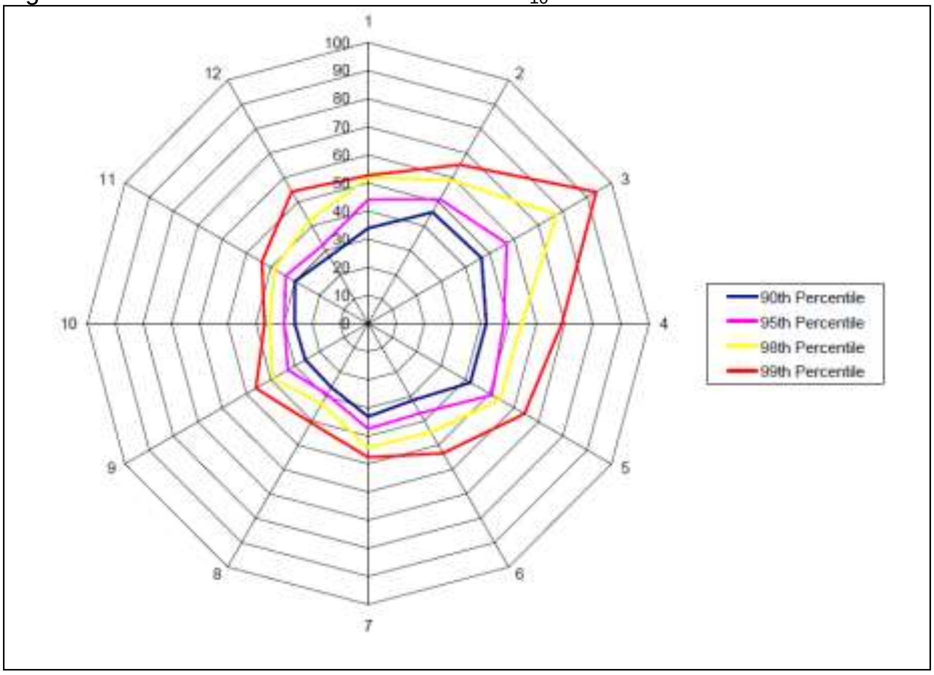


Figure 7: Pollution Rose of Percentile PM_{10} Concentrations



As can be seen from the results, there is a clear influence on PM_{10} concentrations with easterly winds (i.e. from the direction of the poultry sheds). The average PM_{10} concentration increases by a maximum of nearly 12 µg/m^3 for easterly winds and the 95th (and above) percentile concentrations nearly double.

To assess the contribution of the poultry farm 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 did 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 PM_{10} concentrations as a result of emissions from the farm is 2.6 µg/m^3. A similar analysis was 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 19.

Table 19: Percentiles of hourly PM_{10} concentrations measured at Frith Farm.

Percentile	Dataset Unaffected by Farm Emissions	Entire Dataset
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

The results show that there is an increase 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 9 µg/m^3.

The same analysis could not be undertaken for the 24-hour mean concentrations as the wind direction varied throughout the day.

North Dorset DC

Although the most probable "worst case" location for monitoring would have been to the north-east of the site, the location selected for locating a sampler was to the south-west. This location was selected for two reasons. One practical reason was that electrical power to operate the sampler was readily available at that location. The main reason was that it was close to locations of relevant exposure. The exact location was decided on to minimise any effect of nearby trees.

The nature of the location also influenced the choice of sampler. Although it would have been preferable to use a sampler with proven equivalence to the European reference method, the costs and infrastructure involved with locating such a sampler would have made the exercise unviable. As a result of this it was decided to use an OSIRIS optical sampler. This was mounted, at head height, in a weather proof casing on a pole located in the garden of the residential property closest to the poultry farm.

Monitoring commenced on 8 September 2009 and concluded on 10 December 2009. An overall data capture of 94.7% was achieved for PM_{10} with some data being lost due to software problems and some readings being eliminated in ratification as being unreliable. There were two short periods where data were eliminated from the final dataset. The first was a period of 8 hours beginning at midnight on 24 October when the hourly average concentration of PM_{10} jumped from about 1 µg m^{-3} to in excess of 3,000 µg m^{-3}. The second was a period of 14 hours from midday on 12 November when the hourly average concentration of PM_{10} jumped from about 20 µg m^{-3} to almost 400 µg m^{-3}.

For comparison, data from the following Automated Urban and Rural Network (AURN) sites, Bristol St Pauls, Harwell, Narberth, Portsmouth and Plymouth Centre, were downloaded from the National Air Quality Information Archive (NAQIA) for the period of the monitoring exercise. The Bristol, Portsmouth and Plymouth sites were selected as being the closest sites to East Down Farm where particles are measured whilst Harwell and Narberth are rural sites with particle monitoring. These data were only ratified for the period 8 to 30 September and so must be treated with a measure of caution. The data is summarized in Table 20.

Table 20: Monitored Concentrations at East Down Farm in Comparison to those at Background Sites

Site	Metric	PM_{10} (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})
East Down Farm	Period Mean	18.3	7.5
	90th Percentile	27.6	N/A
Bristol St Pauls	Period Mean	16.8	9.5
	90th Percentile	27.7	N/A
Harwell	Period Mean	15.9	6.4
	90th Percentile	22.5	N/A
Narberth	Period Mean	11.6	N/A
	90th Percentile	17.0	N/A
Portsmouth	Period Mean	26.1	7.7
	90th Percentile	32.8	N/A

The concentrations of PM_{10} at East Down Farm during this period were substantially higher than at Narberth in Pembroke but only slightly higher than at Harwell and Bristol St Pauls. They were comparable with those at Plymouth and substantially lower than those recorded at Portsmouth. The concentrations of $PM_{2.5}$ at East Down Farm were generally comparable with those recorded at other sites.

Northern Ireland Environment Agency (NIEA)

The NIEA has undertaken PM_{10} monitoring in the vicinity of three poultry farms in Northern Ireland. The sampling methodology employed and the results obtained during each of these surveys are described below.

Eglish

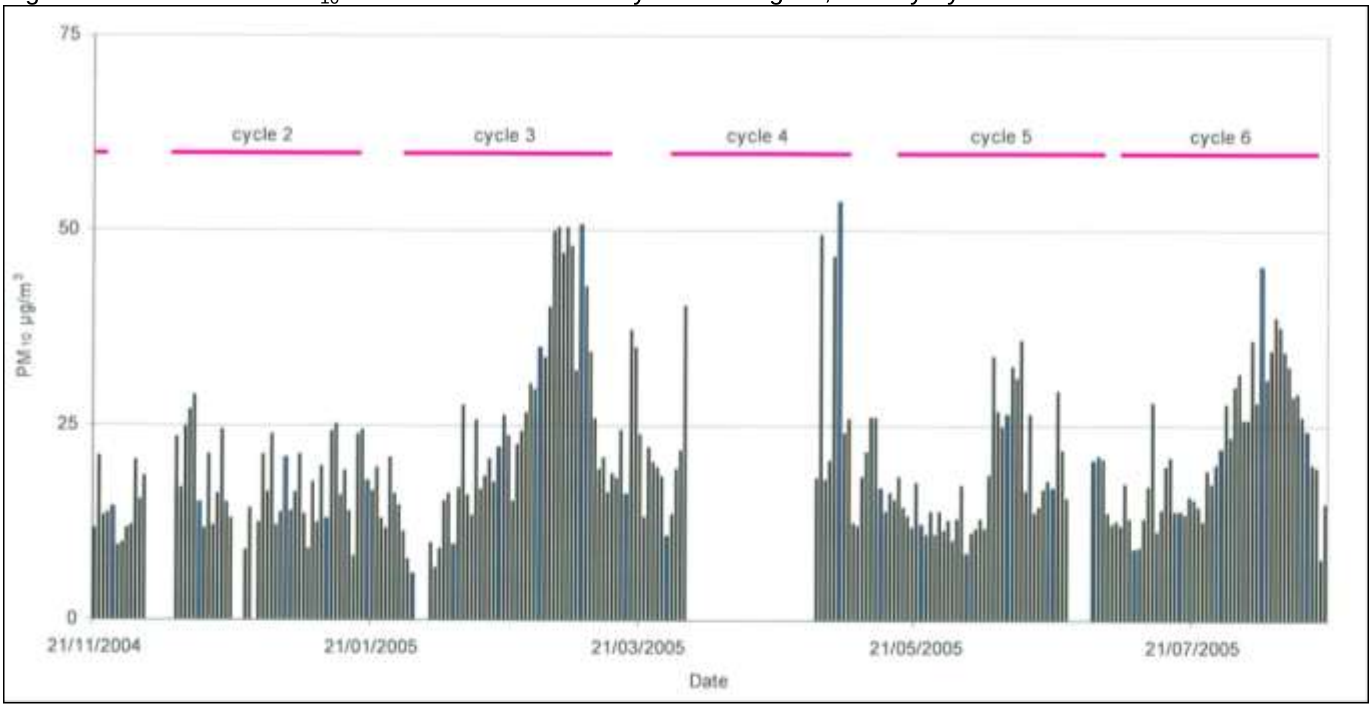
A TEOM analyser was used to measure PM_{10} at a farm in Eglish, County Tyrone, between November 2004 and August 2005. PM_{10} measurements made by the TEOM were adjusted by multiplying the data by 1.3 to estimate gravimetric equivalent concentrations.

The equipment was located in a farmyard, approximately 40 m from the nearest poultry house, with poultry houses located on a bearing of between 230 and 10° of the analyser. There were a number of occasions when the mains power to the PM_{10} sampling unit was interrupted and full daily data was not available. A daily average concentration was therefore only calculated from hourly values for those days on which eighteen hours or more of valid data was available. The analyser was located at the farm for a total of 243 days, with daily average values calculated for 227 of these days (giving a data capture rate of approximately 93%).

The lowest 24 hour mean PM_{10} concentration recorded was 5.9 µg/m^3 on 30th January 2005. The highest 24 hour mean PM_{10} concentration recorded was 53.7 µg/m^3 on 4th May 2005. The overall average PM_{10} concentration over 227 days was 20.6 µg/m^3. The 24 hour mean PM_{10} concentration exceeded 50 µg/m^3 on 4 days i.e. 3rd March 2005, 5th March 2005, 8th March 2005 and 4th May 2005.

The results from this study are illustrated graphically in Figure 8 together with the bird rearing cycles which took place at the farm during this period. Each rearing cycle lasts approximately 30 days and starts with hatching and ends with dispatch. It can be seen that concentrations tend to be higher at the end of a rearing cycle when the birds are bigger.

Figure 8: Monitored PM_{10} Concentrations at Poultry Farm in Eglish, County Tyrone



Augher

A TEOM PM_{10} monitoring unit was operated for 415 days at a farm in Augher between 26th October 2005 and 15th December 2006. The overall average PM_{10} concentration determined was 22 µg/m^3. The daily mean PM_{10} concentration attributed to the chicken rearing process exceeded 50 µg/m^3 on 12 days. During the monitoring period there were a total of eight chicken rearing cycles.

PM_{10} concentrations were measured using a Rupprecht and Patashnick TEOM series 1400a particulate monitor (ALK 275A). The PM_{10} concentrations were logged in 30 minute, one hour and 24 hour intervals. PM_{10}

measurements made by the TEOM were adjusted by multiplying the data by 1.3 to estimate gravimetric equivalent concentrations.

There were a number of occasions when the mains power to the PM_{10} sampling unit was interrupted and full daily data was not available. Daily average concentrations were therefore only calculated from hourly values for those days on which eighteen hours or more of valid data was available.

There were eight chicken rearing cycles at the farm during the measurement period. The chicken rearing cycle consisted of placing day old hatchlings in the chicken houses and removing them after about 40 days. The houses were then cleaned and prepared for the next batch of chickens. The results of the monitoring are shown in Table 21.

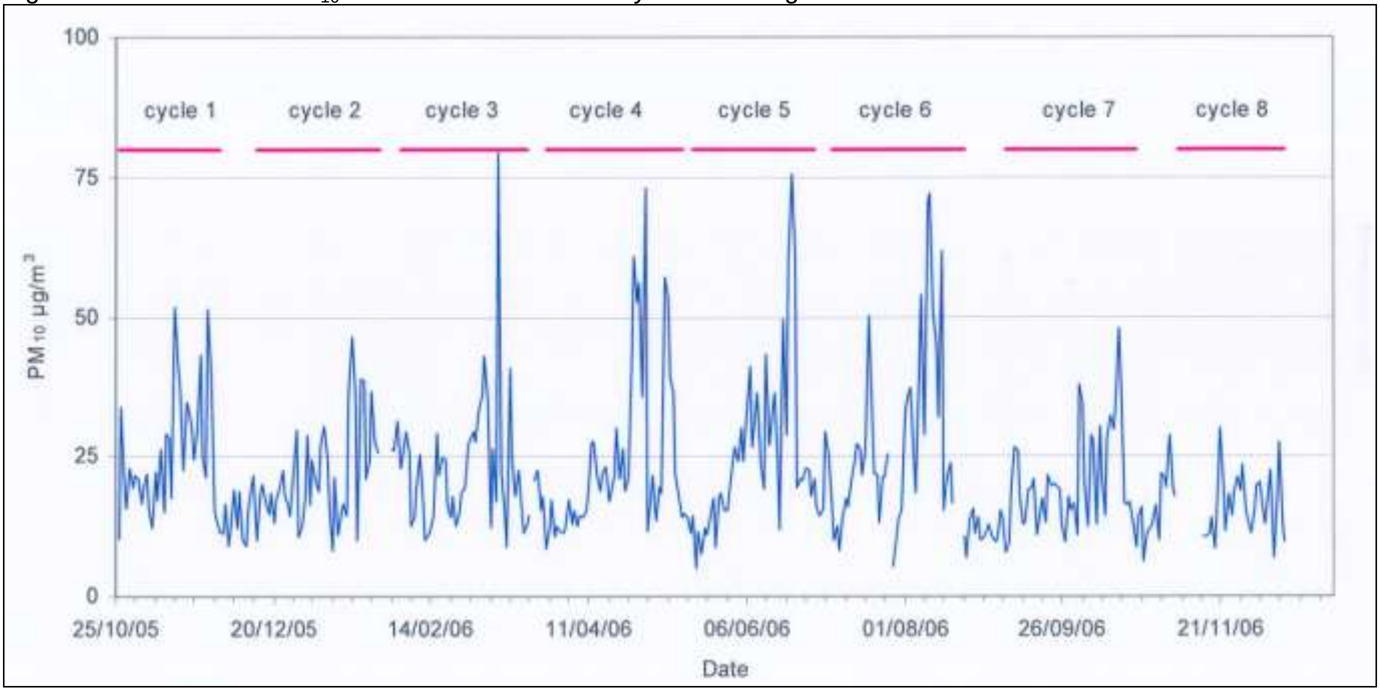
Table 21: Monitored PM_{10} Concentrations at Poultry Farm in Augher

Parameter	Measured Value
Average PM_{10} concentration	22 µg/m^3
90th percentile of daily mean PM_{10} concentrations	37 µg/m^3
Number of daily mean PM_{10} concentrations exceeding 50 µg/m^3	18
Number of daily mean PM_{10} concentrations exceeding 50 µg/m^3 attributed to the chicken rearing process	12
Number of days of valid data	397
Number of days data lost	18
Data Capture Rate	95.7 %

The overall average PM_{10} concentration during the monitoring period from 26/10/05 until 14/12/06 was 22 µg/m^3 and the 24 hour average PM_{10} concentration exceeded 50 µg/m^3 on 18 days. Twelve of the daily average exceedences were attributed to the chicken rearing process. The daily average exceedences on the other six days coincided with the laying of stones around the chicken houses and with agricultural work carried out in neighbouring fields. The 90th percentile daily average concentration was found to be 37 µg/m^3.

The results from this study are illustrated graphically in Figure 9 together with the bird rearing cycles which took place at the farm during this period.

Figure 9: Monitored PM_{10} Concentrations at Poultry Farm in Augher



Brantry

A TEOM PM_{10} monitoring unit was operated for 403 days at a poultry farm in Brantry between 28th December 2006 and 3rd February 2008. There were 363 valid days of data. The overall average PM_{10} concentration obtained was 16 µg/m^3. The daily mean PM_{10} concentration exceeded 50 µg/m^3 on 6 days. During the monitoring period there were eight chicken rearing cycles.

The TEOM was installed in a field south of the chicken rearing houses. The chicken houses were in the range 340° to 70° referenced to magnetic North from the sampling equipment. The PM_{10} concentrations were analysed using a Rupprecht and Patashnick TEOM series 1400A particulate monitor (ALK 275A). PM_{10} concentrations were logged over 30 minute, one hour and 24 hour intervals. The TEOM was fitted with a Filter Dynamics Measurement System (FDMS) on 31st July 2007. The FDMS allows the PM_{10} results from the TEOM to be compared directly with the results obtained using gravimetric methods.

The PM_{10} measurements obtained before the FDMS was fitted on 31st July 2007 were adjusted by multiplying the data by 1.3. No correction was applied to the PM_{10} data obtained using the FDMS equipment after 31st July 2007.

There were teething problems with the new system which caused the TEOM to be offline for 10 days during August 2007. The TEOM had insufficient channels to record wind speed and direction data after the FDMS was fitted on 31st July 2007. To correct this problem Environmental Monitoring Systems fitted an external data logger to manage all the data from the unit. As a result of this problem no wind speed or direction data was recorded for the period 30 July 2007 to 30 August 2007.

There were a number of occasions when the mains power to the PM_{10} sampling unit was interrupted and full daily data was not available. A daily average concentration was therefore only calculated from hourly values for those days on which eighteen hours or more of valid data was available.

There were eight chicken rearing cycles at the farm during the measurement period. The chicken rearing cycle consisted of placing day old hatchlings in the chicken houses and removing them after about 40 days. The houses were then cleaned and prepared for the next batch of chickens. The results from the monitoring are shown in Table 22.

Table 22: Monitored PM_{10} Concentrations at Poultry Farm in Brantry

Parameter	Measured Value
Average PM_{10} concentration	16 µg/m^3
90th percentile of daily mean PM_{10} concentrations	31 µg/m^3
Number of daily mean PM_{10} concentrations exceeding 50 µg/m^3	6
Number of daily mean PM_{10} concentrations exceeding 50 µg/m^3 attributed to the chicken rearing process	5
Number of days of valid data	363
Number of days data lost	40
Data Recovery Rate	90%

The overall average PM_{10} concentration during the monitoring period from 28/12/06 until 3/2/08 was 16 µg/m^3 and the 24 hour average PM_{10} concentration exceeded 50 µg/m^3 on six days. Five of the daily average exceedences were attributed to the chicken rearing process. The daily average exceedence on one day coincided with the burning of bushes in neighbouring fields. The 90th percentile daily average concentration was found to be 31 µg/m^3.

Figure 10: Monitored PM_{10} Concentrations at Poultry Farm in Brantry

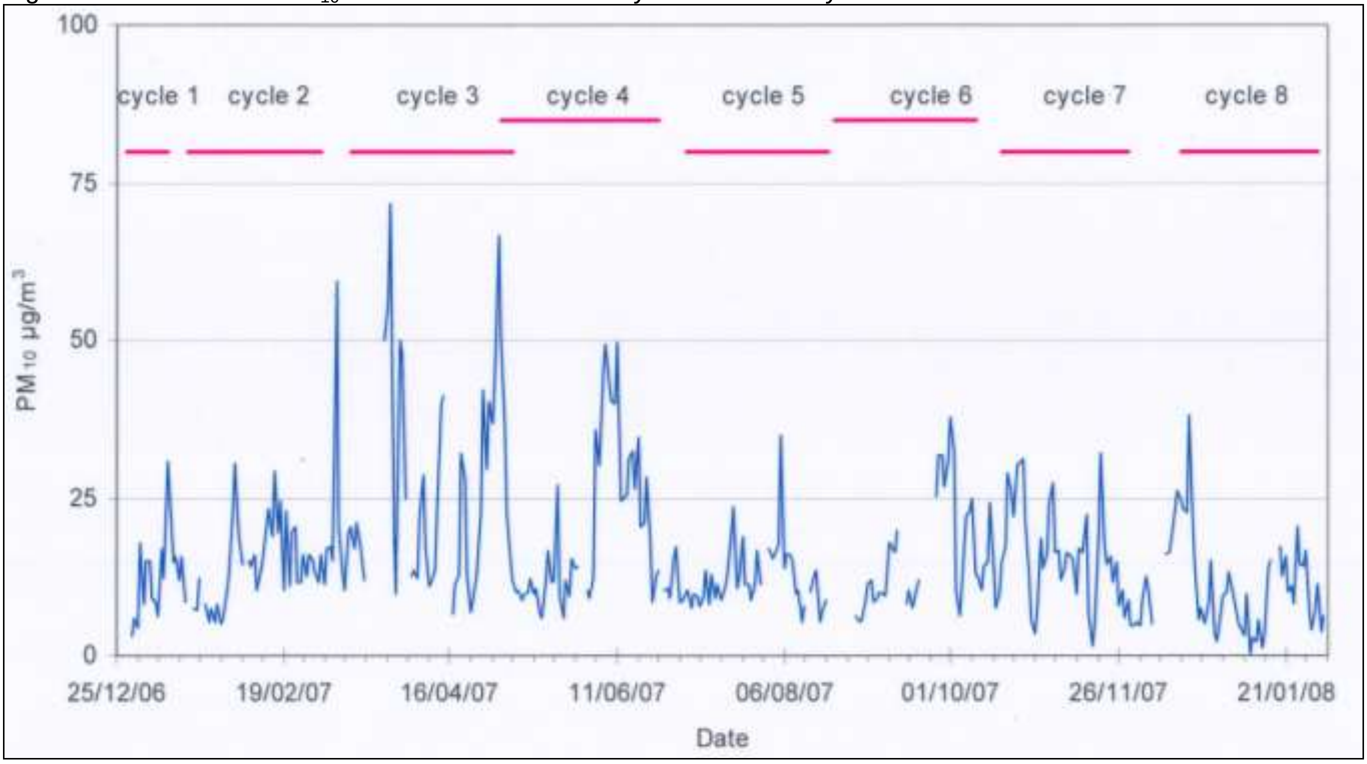
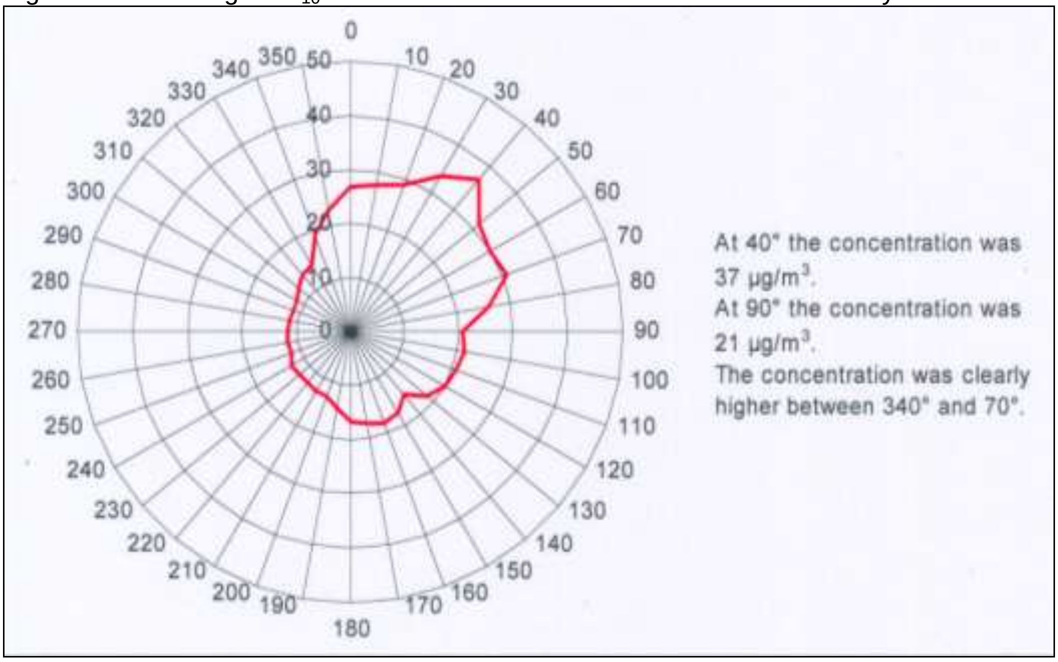


Figure 11: Average PM_{10} Concentrations versus Wind Direction at Poultry Farm in Brantry



Environment Agency

Pen Lôn

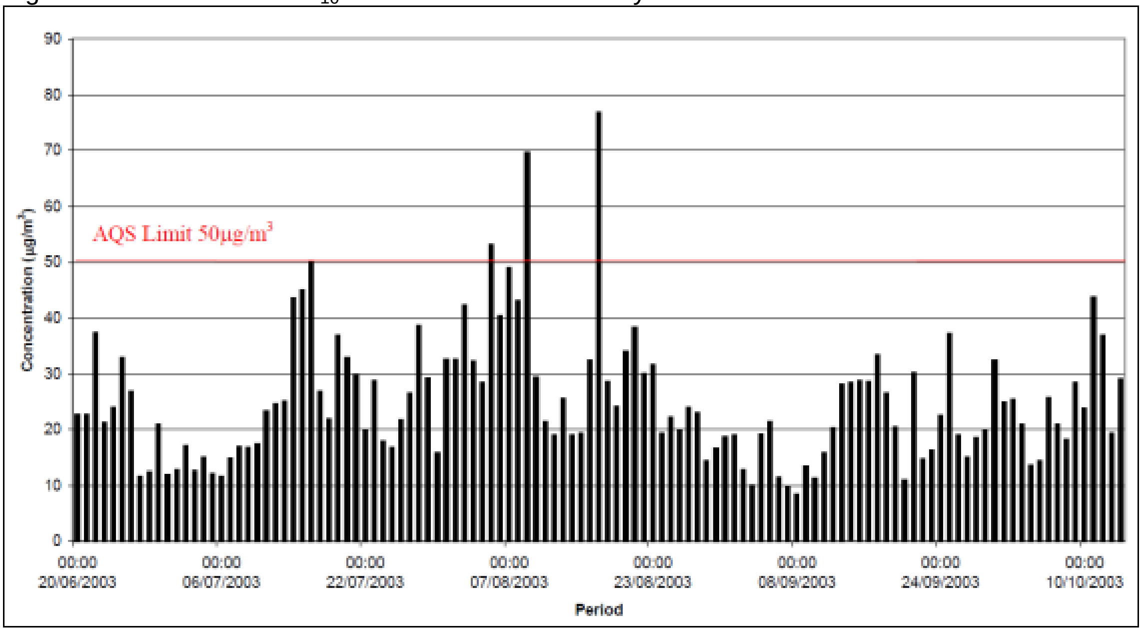
The Environment Agency's Monitoring and Assessment (M&A) unit carried out a study of ambient air quality in the vicinity of Pen Lôn poultry farm, in Newborough, Anglesey over 119 days between 19th June 2003 and 15th October 2003[46]. The study was undertaken on behalf of Environment Agency Wales and in conjunction with the Welsh Assembly Government and Anglesey County Council.

M&A deployed its mobile monitoring facility (MMF) to the south of the Model village, just off the A4080 in Pen Lôn, Newborough. The unit was located such that the poultry sheds were at a bearing of 130° - 225°. Between 19th June 2003 and 15th October 2003 (119 days) airborne PM_{10} concentrations were measured (at a height of 2m above ground) using a TEOM instrument. A factor of 1.3 was applied to estimate gravimetric equivalent concentrations. Data capture over the monitoring over the period was 96%.

The TEOM filter collected during the monitoring study was characterised using scanning electron microscopy with energy dispersive x-ray spectrometry (SEM/EDS) for particle size, type and relative frequency. The report concludes that the sample was dominated by sulphate and chloride salts. However, the characterisation also discovered the presence of large (20-50µm) flakes of skin which was considered likely to be a feature of exfoliated skin associated with litter from poultry units.

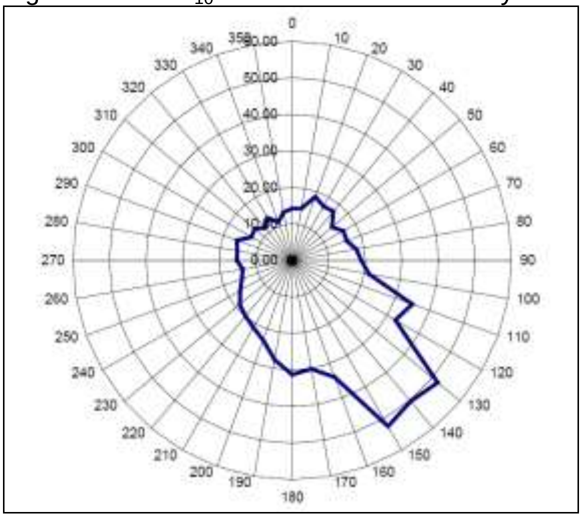
The mean PM_{10} concentration measured over the monitoring period at the MMF was 25.2 µg/m^3. Figure 12 shows the 24-hour (midnight-midnight) mean concentrations for the monitoring site, which shows that the maximum 24-hour PM_{10} concentration during the monitoring period was 76.9 µg/m^3. The results show that the 24-hour (midnight-midnight) mean concentration was greater than 50 µg/m^3 on four days during the monitoring period. If the assumption is made that the conditions during the monitoring period were representative of a typical year then the 24-hour (midnight-midnight) mean concentration limit of 50 µg/m^3 would have been expected to be exceeded on 12 days during the year. Therefore it is unlikely that either of the AQS objectives for PM_{10} would be exceeded.

Figure 12: Monitored PM_{10} Concentrations at Poultry Farm in Pen Lôn



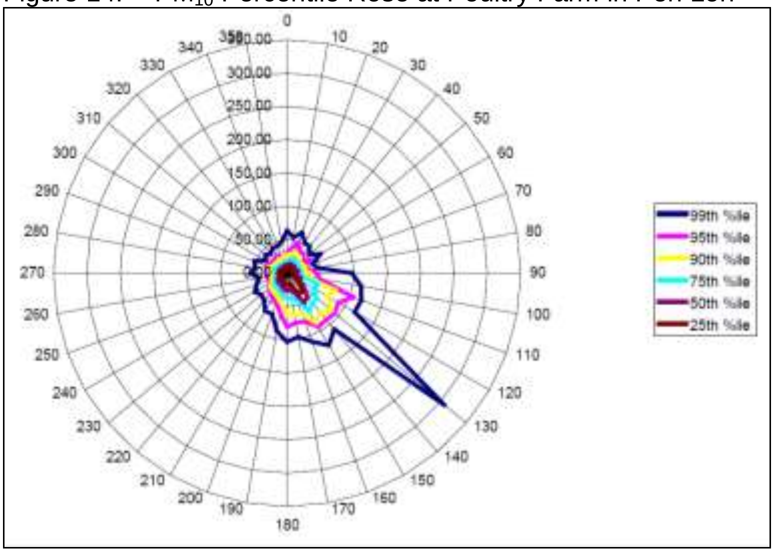
A radial plot of mean PM_{10} concentrations against wind direction for wind speeds above 0.5 m/s recorded at the MMF site is shown in Figure 13. The plot indicates that the highest average PM_{10} concentrations measured at the monitoring site were >50 µg/m^3 (without gravimetric correction) and came from wind directions between 130° and 150°, which encompassed the direction of the poultry farm (130°- 225°).

Figure 13: PM_{10} Pollution Rose at Poultry Farm in Pen Lôn



An array of plots showing the contribution to PM_{10} loading at the monitoring site for different percentiles was also produced. The plots show that the contribution from the sources between 130° and 150° can be seen to affect each percentile plot down to the 25th percentile. This indicates that the sources in this segment emit continuously and commonly affect the PM_{10} concentrations at the monitoring site when the wind is from these directions.

Figure 14: PM_{10} Percentile Rose at Poultry Farm in Pen Lôn



Cubley

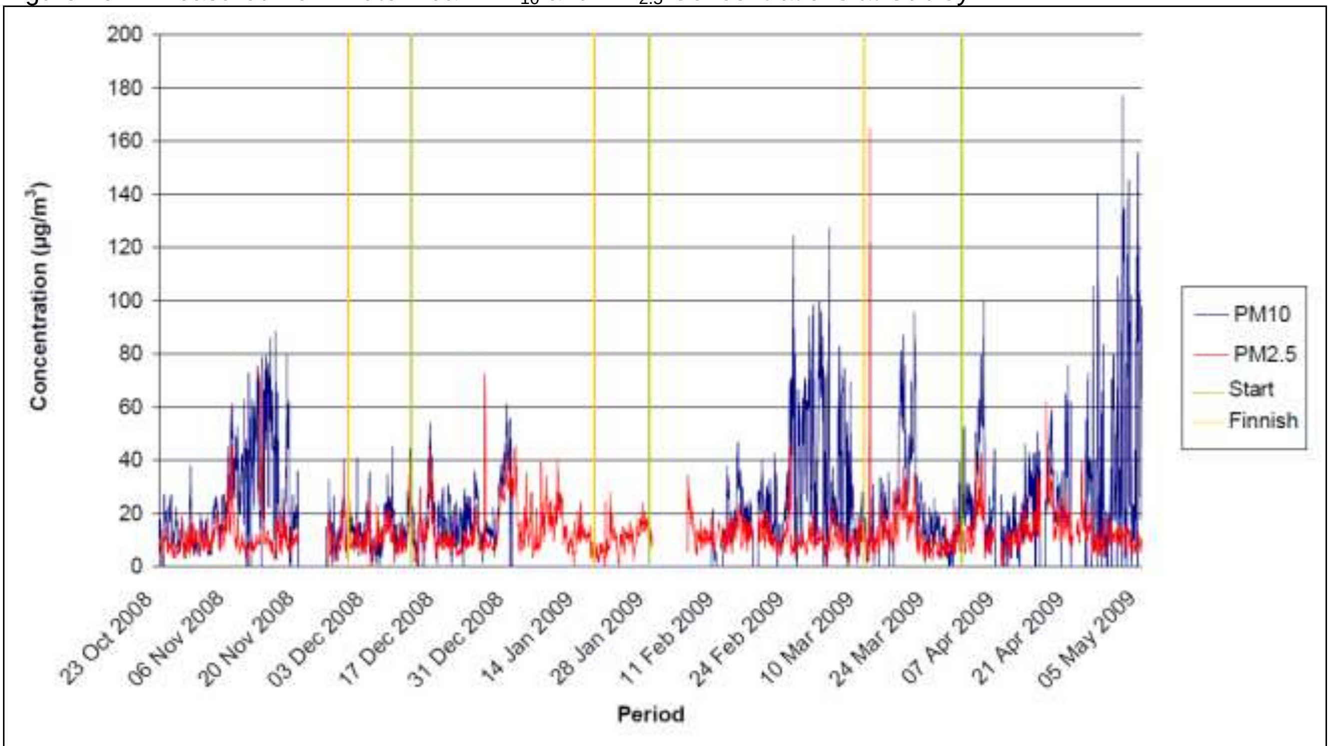
The Environment Agency's Ambient Air Monitoring Team (AAM Team), on behalf of Midlands Region, carried out a study to investigate ambient air quality in the vicinity of a poultry farm at Cubley in Derbyshire.

The Poultry farm consists of six poultry sheds, which house broiler chickens. The capacity of the sheds stated within the permit is 70,000 birds, but this can vary as the sheds are not always fully stocked for each cycle. The growth cycles of the poultry last for around seven weeks, there is usually a short period following where the sheds are empty.

The AAM team deployed its mobile monitoring facility on the grounds of Stoneleigh cottage farm in a rural area. A poultry farm is located on the premises of Stoneleigh cottage farm. There were a number of agricultural practices being carried out n the neighbouring fields of the monitoring site, including slurry spreading and animal farming. The poultry farm is located at a bearing of 130° - 260° from the Mobile Monitoring Facility (MMF).

Between 23 October 2008 and 5 May 2009 (195 days) airborne PM_{10} concentrations at the MMF were measured (at a height of 2m above ground) using TEOM instruments. Successful data collection for PM_{10} over the period was 71%. A time series plot of 15-minute PM_{10} (and $PM_{2.5}$) concentrations over the monitoring period is shown in Figure 15. Markers have been placed on the graph to indicate the start and finish date of the growth cycles at the poultry farm. Activities within the growth cycle (start-finish) include thinning (1-2 days) and catching of poultry (1-3 days). Activities outside of the growth cycles include cleaning (1-2 days).

Figure 15: Measured 15-Minute Mean PM_{10} and $PM_{2.5}$ Concentrations at Cubley



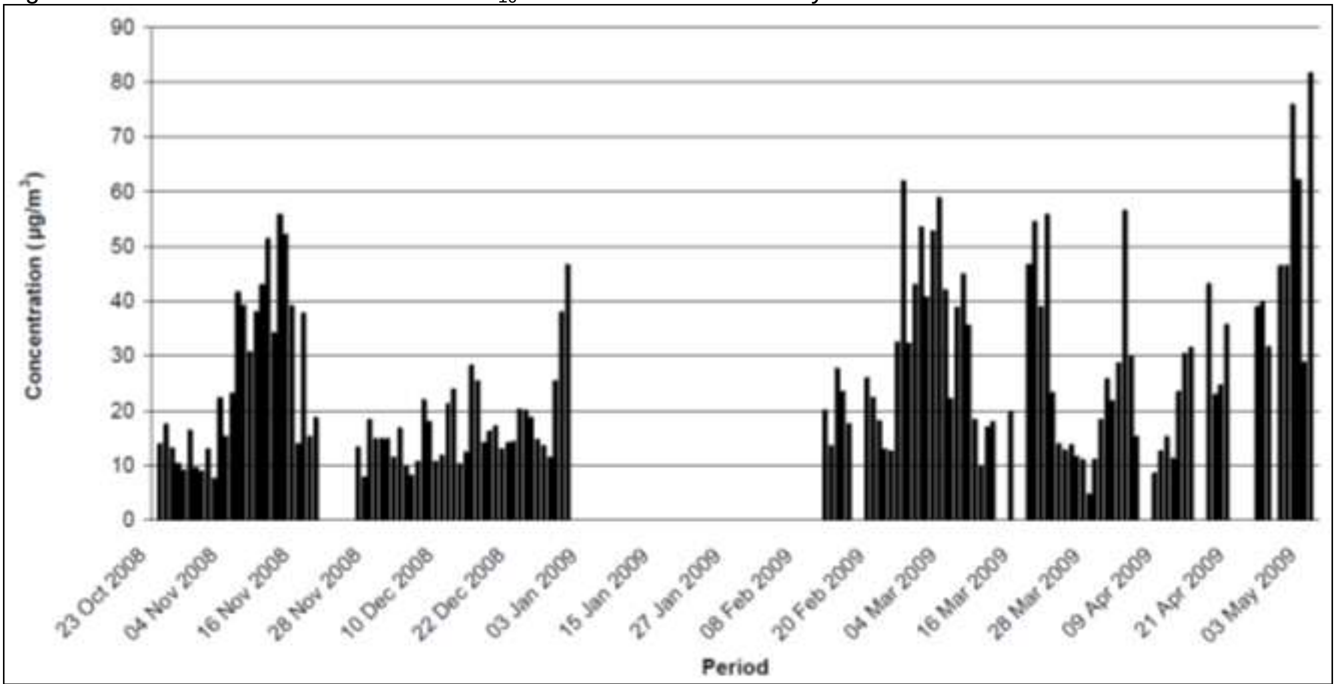
As a consequence of PM_{10} measurements being taken using a TEOM instrument, adjustments should be made using FDMS data, where available, for PM_{10}. FDMS data acquired from Kings College London (KCL) Volatile Correction Model (VCM) has been used to correct the PM_{10} data from the MMF.

The mean PM_{10} concentration over the monitoring period at the MMF2 was 25.4 µg/m^3. If it is assumed that the conditions during the monitoring periods are representative of a typical year, then the results indicate that the AQS annual mean objective would not be exceeded at the monitoring site.

Figure 16 shows that for PM_{10}, the 24-hour (midnight-midnight) mean concentration at the MMF was greater than 50 µg/m^3 on 13 occasions during the monitoring period, the maximum concentration being 81.5 µg/m^3. 10 of the 13 exceedences occurred later than 26 days into the poultry cycle. One of the exceedences occurred on the 5th day of a cycle and two of the exceedences occurred when the sheds were empty.

If it is assumed that the conditions during the monitoring period are representative of a typical year, then over a year the 50 µg/m^3 level for 24-hour (midnight-midnight) mean concentrations would be exceeded on 37 occasions and thus the air quality objective for 24-Hour (midnight-midnight) mean PM_{10} concentrations would be exceeded at the monitoring site.

Figure 16: Measured 24-Hour Mean PM_{10} Concentrations at Cubley



The periods where PM_{10} 1-hour concentrations (µg/m^3) at the monitoring sites increased significantly above the average level have been considered as separate pollution events and have been examined in greater depth. For the purposes of this study the highest five recorded events were individually considered and the association between recorded PM_{10} levels and the wind direction and wind speed at that time examined. The results are summarised in Table 23.

Table 23: Maximum Measured 1-Hour Concentrations at Cubley

Pollution Event	Cycle Day	Date	Time	Maximum 1-hour concentration ($\mu g/m^3$)	Wind direction (degrees)	Wind speed (m/s)
1	31	01/05/09	15:00	177	226	2.3
2	34	04/05/09	15:00	156	236	3.7
3	32	02/05/09	19:00	145	254	1.1
4	28	26/04/09	18:00	140	227	1.1
5	36	04/03/09	16:00	127	216	2.3

Table 23 shows that high levels of PM_{10} were recorded at the monitoring site when the wind was coming from between 216° - 254°, i.e. in the direction of the poultry farm, at wind speeds of 1.1 - 3.7 m/s.

The pollution events occurred between the hours of 15:00 - 19:00. Two of the pollution episodes (04/05/09 & 04/03/09) occurred on days within the growth cycle where thinning was undertaken. All five pollution episodes occurred at a date which was later than 27 days into a growth cycle, with the length of a growth cycle during the study period ranging from 36-42 days.

Appendix B: PM_{10} Increments from Poultry Farms

Sway

An estimated incremental contribution from the monitoring study undertaken in Sway on behalf of New Forest District Council has not been calculated, given that the analyser was located in close proximity to two separate poultry farms a waste transfer station and a road. It was therefore considered that the incremental contribution of the poultry farms could not be estimated with a satisfactory degree of confidence given that the waste transfer station, and the road to an extent, would be likely to contribute to PM_{10} concentrations.

Augher

Given the rural nature of the site, background concentrations were sourced from the Northern Ireland Air website for the Lough Navar rural background monitoring site. Background concentrations were also sourced from the urban background sites at Cookstown, Dungannon Lambfields and Strabane Springhill Park. Comparison of the measured concentrations at these urban background sites to those at Augher suggested that the urban background concentrations were not representative of background concentrations at Augher, given that on the majority of days during the survey period, measured concentrations at the Augher farm were below those at these urban background concentrations.

For those days where daily mean PM_{10} concentrations were not available for the Lough Navar site, background PM_{10} concentrations from the Dungannon Lambfields site were used, as this was considered to be the most representative of the three other sites. This was only necessary for a total of six days during the survey period.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero.

Table 24: Calculation of Incremental Contribution of Augher Poultry Farm to PM_{10} Concentrations

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
26/10/2005	10	11	0
27/10/2005	34	22	12
28/10/2005	20	12	8
29/10/2005	16	10	6
30/10/2005	23	13	10
31/10/2005	19	9	10
01/11/2005	22	10	12
02/11/2005	21	11	10
03/11/2005	17	8	9
04/11/2005	20	9	11
05/11/2005	22	11	11
06/11/2005	16	11	5
07/11/2005	12	7	5
08/11/2005	22	9	13
09/11/2005	17	9	8
10/11/2005	26	14	12
11/11/2005	15	9	6
12/11/2005	29	11	18
13/11/2005	28	9	19
14/11/2005	18	6	12
15/11/2005	52	12	40

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
16/11/2005	41	10	31
17/11/2005	38	11	27
18/11/2005	23	14	9
19/11/2005	35	10	25
20/11/2005	34	11	23
21/11/2005	30	11	19
22/11/2005	25	9	16
23/11/2005	30	10	20
24/11/2005	43	8	35
25/11/2005	25	13	12
26/11/2005	21	14	7
27/11/2005	51	7	44
28/11/2005	40	8	32
29/11/2005	15	6	9
30/11/2005	14	6	8
01/12/2005	12	5	7
02/12/2005	11	8	3
03/12/2005	17	11	6
04/12/2005	9	8	1
05/12/2005	12	9	3
06/12/2005	19	8	11
07/12/2005	12	9	3
08/12/2005	19	9	10
09/12/2005	10	7	3
10/12/2005	9	7	2
11/12/2005	16	10	6
12/12/2005	20	7	13
13/12/2005	22	10	12
14/12/2005	10	8	2
15/12/2005	18	15	3
16/12/2005	20	15	5
17/12/2005	17	8	9
18/12/2005	15	8	7
19/12/2005	18	10	8
20/12/2005	13	7	6
21/12/2005	17	8	9
22/12/2005	20	12	8
23/12/2005	23	11	12
24/12/2005	18	9	9
25/12/2005	16	8	8
26/12/2005	14	7	7
27/12/2005	22	9	13
28/12/2005	30	12	18
29/12/2005	11	5	6
30/12/2005	13	7	6
31/12/2005	18	11	7
01/01/2006	29	14	15
02/01/2006	16	7	9

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
03/01/2006	24	8	16
04/01/2006	21	11	10
05/01/2006	19	12	7
06/01/2006	27	15	12
07/01/2006	31	16	15
08/01/2006	25	16	9
09/01/2006	16	9	7
10/01/2006	8	6	2
11/01/2006	21	10	11
12/01/2006	11	7	4
13/01/2006	15	7	8
14/01/2006	17	7	10
15/01/2006	15	10	5
16/01/2006	37	8	29
17/01/2006	46	11	35
18/01/2006	36	9	27
19/01/2006	10	6	4
20/01/2006	39	13	26
21/01/2006	39	14	25
22/01/2006	21	13	8
23/01/2006	24	15	9
24/01/2006	37	20	17
25/01/2006	28	17	11
26/01/2006	26	11	15
27/01/2006	No Data	12	N/A
28/01/2006	No Data	10	N/A
29/01/2006	No Data	13	N/A
30/01/2006	No Data	21	N/A
31/01/2006	26	19	7
01/02/2006	26	19	7
02/02/2006	31	27	4
03/02/2006	23	18	5
04/02/2006	25	11	14
05/02/2006	29	19	10
06/02/2006	26	17	9
07/02/2006	12	8	4
08/02/2006	14	8	6
09/02/2006	19	7	12
10/02/2006	25	12	13
11/02/2006	17	12	5
12/02/2006	10	6	4
13/02/2006	11	6	5
14/02/2006	12	4	8
15/02/2006	14	7	7
16/02/2006	29	7	22
17/02/2006	22	11	11
18/02/2006	25	10	15
19/02/2006	24	13	11

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
20/02/2006	16	11	5
21/02/2006	14	7	7
22/02/2006	18	11	7
23/02/2006	13	9	4
24/02/2006	15	9	6
25/02/2006	19	13	6
26/02/2006	19	12	7
27/02/2006	27	8	19
28/02/2006	28	7	21
01/03/2006	29	5	24
02/03/2006	28	5	23
03/03/2006	33	8	25
04/03/2006	36	7	29
05/03/2006	43	6	37
06/03/2006	35	7	28
07/03/2006	12	5	7
08/03/2006	26	5	21
09/03/2006	17	7	10
10/03/2006	79	14	65
11/03/2006	22	6	16
12/03/2006	14	18	0
13/03/2006	9	6	3
14/03/2006	41	7	34
15/03/2006	25	17	8
16/03/2006	18	12	6
17/03/2006	23	16	7
18/03/2006	18	14	4
19/03/2006	11	7	4
20/03/2006	13	8	5
21/03/2006	15	9	6
22/03/2006	No Data	12	N/A
23/03/2006	21	17	4
24/03/2006	23	18	5
25/03/2006	15	12	3
26/03/2006	18	11	7
27/03/2006	8	5	3
28/03/2006	12	10	2
29/03/2006	17	10	7
30/03/2006	11	8	3
31/03/2006	13	7	6
01/04/2006	12	8	4
02/04/2006	11	9	2
03/04/2006	12	10	2
04/04/2006	17	11	6
05/04/2006	13	7	6
06/04/2006	15	12	3
07/04/2006	13	9	4
08/04/2006	15	11	4

Date	Monitored Daily mean PM_{10} Concentration at Augher (µg/m^3)	Monitored Daily Mean PM_{10} Concentration at Lough Navar (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
09/04/2006	14	8	6
10/04/2006	15	7	8
11/04/2006	18	13	5
12/04/2006	28	20	8
13/04/2006	28	17	11
14/04/2006	22	10	12
15/04/2006	19	9	10
16/04/2006	22	13	9
17/04/2006	23	9	14
18/04/2006	17	9	8
19/04/2006	18	18	0
20/04/2006	22	11	11
21/04/2006	30	10	20
22/04/2006	21	9	12
23/04/2006	26	10	16
24/04/2006	19	9	10
25/04/2006	21	14	7
26/04/2006	44	14	30
27/04/2006	61	22	39
28/04/2006	53	19	34
29/04/2006	56	13	43
30/04/2006	36	8	28
01/05/2006	73	9	64
02/05/2006	12	7	5
03/05/2006	18	14	4
04/05/2006	22	13	9
05/05/2006	13	10	3
06/05/2006	19	13	6
07/05/2006	18	13	5
08/05/2006	57	37	20
09/05/2006	53	28	25
10/05/2006	39	27	12
11/05/2006	36	19	17
12/05/2006	22	13	9
13/05/2006	18	13	5
14/05/2006	14	9	5
15/05/2006	15	10	5
16/05/2006	14	9	5
17/05/2006	11	7	4
18/05/2006	14	11	3
19/05/2006	5	7	0
20/05/2006	12	8	4
21/05/2006	7	6	1
22/05/2006	12	8	4
23/05/2006	11	8	3
24/05/2006	14	12	2
25/05/2006	18	13	5
26/05/2006	9	8	1

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
27/05/2006	18	15	3
28/05/2006	19	15	4
29/05/2006	15	12	3
30/05/2006	15	9	6
31/05/2006	19	11	8
01/06/2006	24	14	10
02/06/2006	27	10	17
03/06/2006	24	9	15
04/06/2006	30	15	15
05/06/2006	24	18	6
06/06/2006	33	14	19
07/06/2006	41	21	20
08/06/2006	27	30	0
09/06/2006	33	26	7
10/06/2006	36	29	7
11/06/2006	24	21	3
12/06/2006	19	14	5
13/06/2006	43	17	26
14/06/2006	27	7	20
15/06/2006	33	11	22
16/06/2006	36	9	27
17/06/2006	24	9	15
18/06/2006	12	4	8
19/06/2006	50	6	44
20/06/2006	29	9	20
21/06/2006	60	17	43
22/06/2006	76	12	64
23/06/2006	61	8	53
24/06/2006	20	14	6
25/06/2006	21	8	13
26/06/2006	21	9	12
27/06/2006	23	11	12
28/06/2006	22	25	0
29/06/2006	18	7	11
30/06/2006	21	11	10
01/07/2006	16	11	5
02/07/2006	15	9	6
03/07/2006	16	10	6
04/07/2006	29	18	11
05/07/2006	25	12	13
06/07/2006	16	10	6
07/07/2006	10	7	3
08/07/2006	12	7	5
09/07/2006	8	9	0
10/07/2006	14	9	5
11/07/2006	17	12	5
12/07/2006	16	14	2
13/07/2006	21	17	4

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
14/07/2006	24	15	9
15/07/2006	27	21	6
16/07/2006	26	17	9
17/07/2006	22	12	10
18/07/2006	26	19	7
19/07/2006	50	34	16
20/07/2006	41	33	8
21/07/2006	22	12	10
22/07/2006	22	11	11
23/07/2006	13	9	4
24/07/2006	21	11	10
25/07/2006	21	12	9
26/07/2006	25	9	16
27/07/2006	No Data	8	N/A
28/07/2006	5	5	0
29/07/2006	11	7	4
30/07/2006	14	10	4
31/07/2006	15	9	6
01/08/2006	33	12	21
02/08/2006	35	7	28
03/08/2006	37	8	29
04/08/2006	24	11	13
05/08/2006	18	8	10
06/08/2006	42	5	37
07/08/2006	54	7	47
08/08/2006	29	8	21
09/08/2006	71	14	57
10/08/2006	72	8	64
11/08/2006	51	6	45
12/08/2006	44	6	38
13/08/2006	32	6	26
14/08/2006	62	5	57
15/08/2006	15	7	8
16/08/2006	21	6	15
17/08/2006	24	6	18
18/08/2006	17	11	6
19/08/2006	No Data	13	N/A
20/08/2006	No Data	8	N/A
21/08/2006	No Data	6	N/A
22/08/2006	11	7	4
23/08/2006	7	9	0
24/08/2006	14	10	4
25/08/2006	16	10	6
26/08/2006	11	12	0
27/08/2006	14	13	1
28/08/2006	10	12	0
29/08/2006	10	11	0
30/08/2006	12	7	5

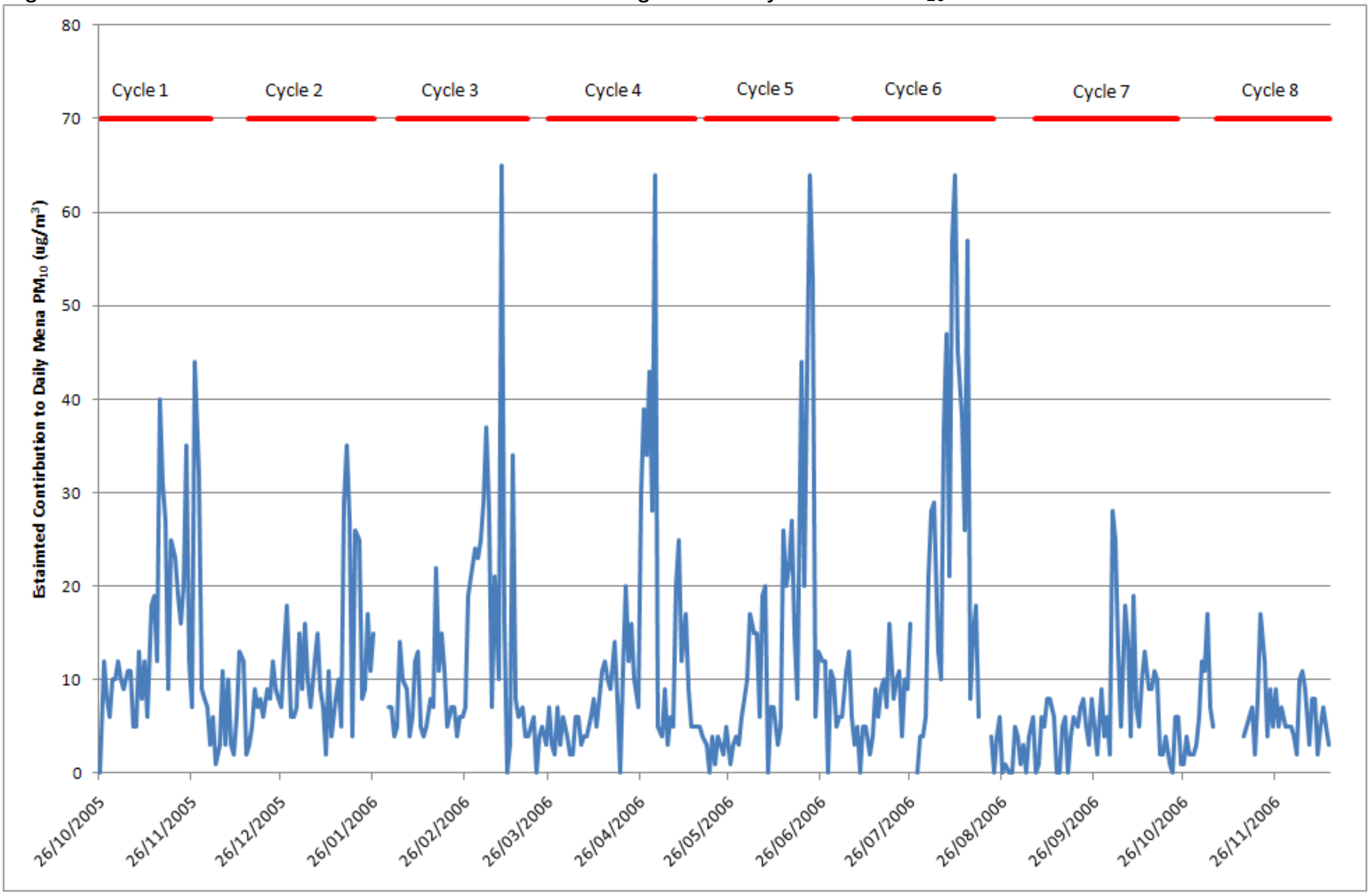
Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
31/08/2006	13	9	4
01/09/2006	11	10	1
02/09/2006	10	7	3
03/09/2006	10	10	0
04/09/2006	15	11	4
05/09/2006	14	8	6
06/09/2006	8	9	0
07/09/2006	10	9	1
08/09/2006	19	13	6
09/09/2006	27	22	5
10/09/2006	26	18	8
11/09/2006	18	10	8
12/09/2006	13	7	6
13/09/2006	13	14	0
14/09/2006	19	26	0
15/09/2006	20	15	5
16/09/2006	21	15	6
17/09/2006	11	12	0
18/09/2006	13	9	4
19/09/2006	18	12	6
20/09/2006	13	8	5
21/09/2006	22	15	7
22/09/2006	20	12	8
23/09/2006	20	15	5
24/09/2006	20	17	3
25/09/2006	19	11	8
26/09/2006	13	8	5
27/09/2006	10	8	2
28/09/2006	18	9	9
29/09/2006	15	11	4
30/09/2006	17	11	6
01/10/2006	11	9	2
02/10/2006	38	10	28
03/10/2006	34	9	25
04/10/2006	21	8	13
05/10/2006	12	7	5
06/10/2006	29	11	18
07/10/2006	28	14	14
08/10/2006	13	9	4
09/10/2006	30	11	19
10/10/2006	21	14	7
11/10/2006	14	9	5
12/10/2006	28	18	10
13/10/2006	32	19	13
14/10/2006	30	21	9
15/10/2006	35	26	9
16/10/2006	48	37	11
17/10/2006	40	30	10

Date	Monitored Daily mean PM_{10} Concentration at Augher (μg/m^3)	Monitored Daily Mean PM_{10} Concentration at Lough Navar (μg/m^3)	Estimated Contribution from Poultry Farm (μg/m^3)
18/10/2006	17	15	2
19/10/2006	16	14	2
20/10/2006	17	13	4
21/10/2006	13	12	1
22/10/2006	9	10	0
23/10/2006	14	8	6
24/10/2006	16	10	6
25/10/2006	6	5	1
26/10/2006	11	10	1
27/10/2006	12	8	4
28/10/2006	13	11	2
29/10/2006	16	14	2
30/10/2006	10	7	3
31/10/2006	22	16	6
01/11/2006	21	9	12
02/11/2006	19	8	11
03/11/2006	29	12	17
04/11/2006	19	12	7
05/11/2006	18	13	5
06/11/2006	No Data	13	N/A
07/11/2006	No Data	11	N/A
08/11/2006	No Data	10	N/A
09/11/2006	No Data	11	N/A
10/11/2006	No Data	10	N/A
11/11/2006	No Data	19	N/A
12/11/2006	No Data	13	N/A
13/11/2006	No Data	13	N/A
14/11/2006	No Data	8	N/A
15/11/2006	11	7	4
16/11/2006	11	6	5
17/11/2006	11	5	6
18/11/2006	14	7	7
19/11/2006	9	7	2
20/11/2006	21	13	8
21/11/2006	30	13	17
22/11/2006	20	8	12
23/11/2006	12	8	4
24/11/2006	18	9	9
25/11/2006	15	10	5
26/11/2006	18	9	9
27/11/2006	21	16	5
28/11/2006	19	12	7
29/11/2006	24	19	5
30/11/2006	15	10	5
01/12/2006	14	9	5
02/12/2006	11	7	4
03/12/2006	15	13	2
04/12/2006	20	10	10

Date	Monitored Daily mean PM_{10} Concentration at Augher ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
05/12/2006	20	9	11
06/12/2006	17	8	9
07/12/2006	13	10	3
08/12/2006	19	11	8
09/12/2006	23	15	8
10/12/2006	7	5	2
11/12/2006	18	13	5
12/12/2006	28	21	7
13/12/2006	13	8	5
14/12/2006	10	7	3

The estimated contributions of the farm to monitored daily mean PM_{10} concentrations shown in the table above are illustrated graphically in Figure 17 in relation to the dates of the rearing cycles at the farm. It can be seen that the highest PM_{10} concentrations are observed towards the end of each rearing cycle.

Figure 17: Estimated Incremental Contribution of Augher Poultry Farm to PM_{10} Concentrations



Eglish

Given the rural nature of the site, background concentrations were sourced from the Northern Ireland Air website for the Lough Navar rural background monitoring site. Background concentrations were also sourced from the urban background sites at Cookstown, Dungannon Lambfields and Strabane Springhill Park. Comparison of the measured concentrations at the urban background sites to those at Eglish suggested that the urban background concentrations were not representative of background concentrations at Eglish, given that on the majority of days during the survey period, monitored concentrations at the Eglish farm were below those at these urban background concentrations.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero. The increment from Eglish Farm is shown in Table 25.

Table 25: Calculation of Incremental Contribution of Eglish Poultry Farm to PM_{10} Concentrations

Date	Monitored Daily mean PM_{10} Concentration at Eglish ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
21/11/2004	12	9	3
22/11/2004	21	18	3
23/11/2004	13	7	6
24/11/2004	14	7	7
25/11/2004	15	11	4
26/11/2004	9	6	3
27/11/2004	10	7	3
28/11/2004	12	7	5
29/11/2004	12	6	6
30/11/2004	20	8	12
01/12/2004	16	7	9
02/12/2004	19	7	12
03/12/2004	No Data	11	N/A
04/12/2004	No Data	8	N/A
05/12/2004	No Data	9	N/A
06/12/2004	No Data	8	N/A
07/12/2004	No Data	10	N/A
08/12/2004	No Data	10	N/A
09/12/2004	24	14	10
10/12/2004	17	9	8
11/12/2004	25	14	11
12/12/2004	27	18	9
13/12/2004	29	19	10
14/12/2004	15	10	5
15/12/2004	12	7	5
16/12/2004	21	15	6
17/12/2004	12	9	3
18/12/2004	16	10	6
19/12/2004	24	10	14
20/12/2004	15	10	5
21/12/2004	13	7	6
22/12/2004	No Data	7	N/A

Date	Monitored Daily mean PM_{10} Concentration at Eglish ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
23/12/2004	No Data	14	N/A
24/12/2004	9	6	3
25/12/2004	14	0	ND
26/12/2004	No Data	13	N/A
27/12/2004	12	8	4
28/12/2004	21	15	6
29/12/2004	16	11	5
30/12/2004	24	9	15
31/12/2004	12	7	5
01/01/2005	14	10	4
02/01/2005	21	15	6
03/01/2005	14	11	3
04/01/2005	16	10	6
05/01/2005	21	11	10
06/01/2005	14	8	6
07/01/2005	9	4	5
08/01/2005	18	10	8
09/01/2005	13	8	5
10/01/2005	20	14	6
11/01/2005	13	11	2
12/01/2005	24	14	10
13/01/2005	25	11	14
14/01/2005	16	7	9
15/01/2005	19	12	7
16/01/2005	14	8	6
17/01/2005	8	5	3
18/01/2005	24	17	7
19/01/2005	24	14	10
20/01/2005	18	11	7
21/01/2005	17	12	5
22/01/2005	20	9	11
23/01/2005	13	9	4
24/01/2005	12	7	5
25/01/2005	21	13	8
26/01/2005	16	7	9
27/01/2005	15	5	10
28/01/2005	11	7	4
29/01/2005	8	5	3
30/01/2005	6	5	1
31/01/2005	No Data	12	N/A
01/02/2005	No Data	6	N/A
02/02/2005	No Data	11	N/A
03/02/2005	10	7	3
04/02/2005	7	3	4
05/02/2005	9	5	4
06/02/2005	15	7	8
07/02/2005	16	9	7
08/02/2005	10	8	2

Date	Monitored Daily mean PM_{10} Concentration at Eglish ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
09/02/2005	17	15	2
10/02/2005	28	18	10
11/02/2005	16	7	9
12/02/2005	13	12	1
13/02/2005	26	18	8
14/02/2005	17	9	8
15/02/2005	19	7	12
16/02/2005	21	8	13
17/02/2005	18	7	11
18/02/2005	22	13	9
19/02/2005	26	15	11
20/02/2005	24	8	16
21/02/2005	15	6	9
22/02/2005	23	8	15
23/02/2005	24	7	17
24/02/2005	27	12	15
25/02/2005	30	14	16
26/02/2005	30	9	21
27/02/2005	35	9	26
28/02/2005	34	8	26
01/03/2005	40	6	34
02/03/2005	50	7	43
03/03/2005	50	8	42
04/03/2005	47	22	25
05/03/2005	51	18	33
06/03/2005	48	8	40
07/03/2005	32	5	27
08/03/2005	51	6	45
09/03/2005	43	6	37
10/03/2005	35	10	25
11/03/2005	26	14	12
12/03/2005	19	11	8
13/03/2005	21	9	12
14/03/2005	16	12	4
15/03/2005	19	15	4
16/03/2005	18	20	0
17/03/2005	24	19	5
18/03/2005	16	11	5
19/03/2005	37	24	13
20/03/2005	35	26	9
21/03/2005	24	10	14
22/03/2005	13	10	3
23/03/2005	22	15	7
24/03/2005	20	14	6
25/03/2005	20	11	9
26/03/2005	19	11	8
27/03/2005	11	9	2
28/03/2005	14	11	3

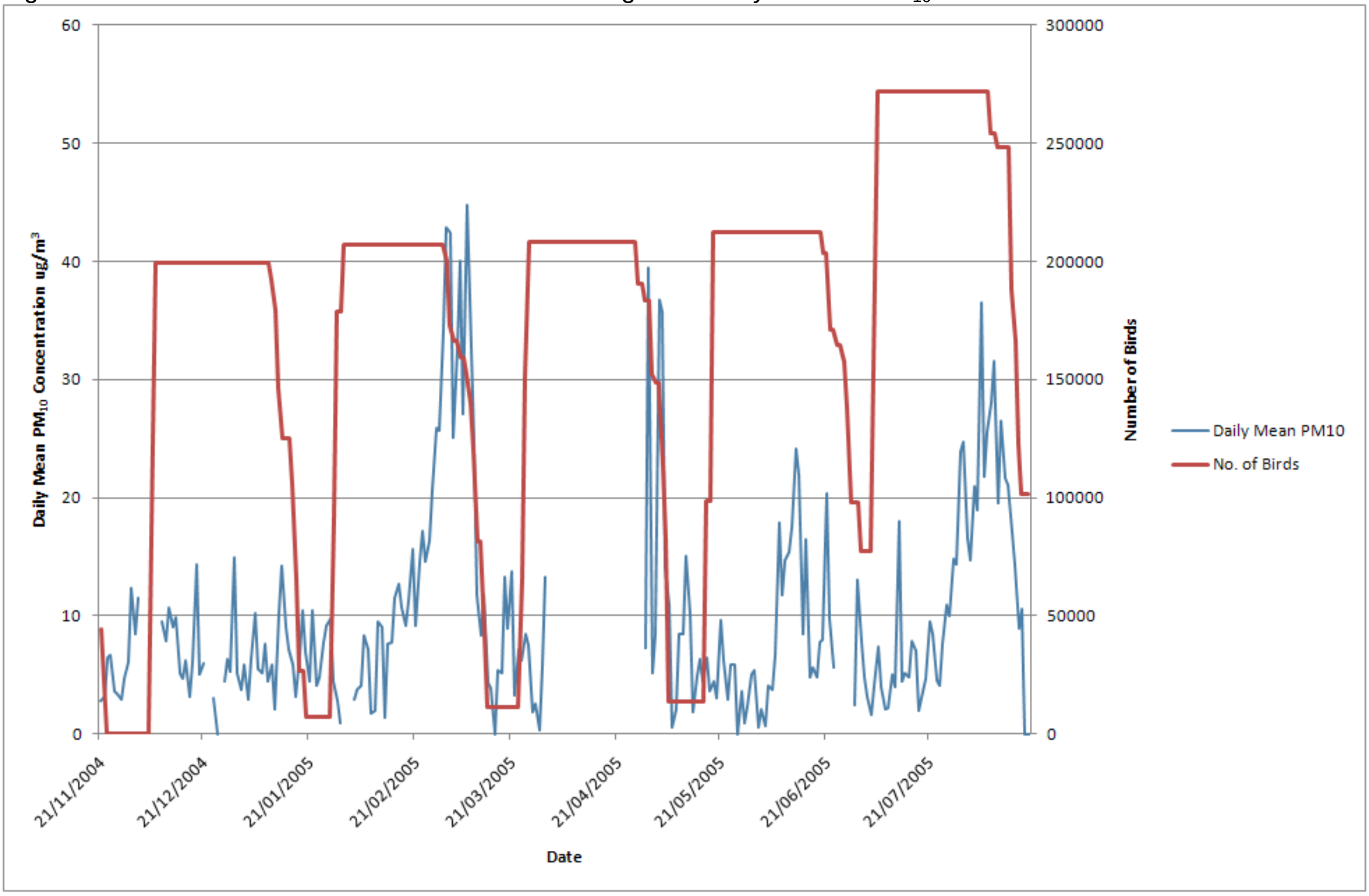
Date	Monitored Daily mean PM_{10} Concentration at Eglish ($\mu g/m^3$)	Monitored Daily Mean PM_{10} Concentration at Lough Navar ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
29/03/2005	19	19	0
30/03/2005	22	16	6
31/03/2005	40	27	13
01/04/2005	No Data	10	N/A
02/04/2005	No Data	19	N/A
03/04/2005	No Data	14	N/A
04/04/2005	No Data	8	N/A
05/04/2005	No Data	6	N/A
06/04/2005	No Data	7	N/A
07/04/2005	No Data	11	N/A
08/04/2005	No Data	11	N/A
09/04/2005	No Data	13	N/A
10/04/2005	No Data	14	N/A
11/04/2005	No Data	9	N/A
12/04/2005	No Data	14	N/A
13/04/2005	No Data	6	N/A
14/04/2005	No Data	10	N/A
15/04/2005	No Data	9	N/A
16/04/2005	No Data	9	N/A
17/04/2005	No Data	7	N/A
18/04/2005	No Data	8	N/A
19/04/2005	No Data	11	N/A
20/04/2005	No Data	14	N/A
21/04/2005	No Data	21	N/A
22/04/2005	No Data	23	N/A
23/04/2005	No Data	23	N/A
24/04/2005	No Data	21	N/A
25/04/2005	No Data	23	N/A
26/04/2005	No Data	13	N/A
27/04/2005	No Data	7	N/A
28/04/2005	No Data	10	N/A
29/04/2005	18	11	7
30/04/2005	50	10	40
01/05/2005	18	13	5
02/05/2005	21	12	9
03/05/2005	47	10	37
04/05/2005	54	18	36
05/05/2005	24	10	14
06/05/2005	26	15	11
07/05/2005	13	12	1
08/05/2005	12	10	2
09/05/2005	19	10	9
10/05/2005	22	13	9
11/05/2005	26	11	15
12/05/2005	26	16	10
13/05/2005	17	15	2
14/05/2005	14	9	5
15/05/2005	16	10	6

Date	Monitored Daily mean PM_{10} Concentration at Eglish (µg/m^3)	Monitored Daily Mean PM_{10} Concentration at Lough Navar (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
16/05/2005	16	11	5
17/05/2005	19	12	7
18/05/2005	15	11	4
19/05/2005	13	9	4
20/05/2005	12	9	3
21/05/2005	18	8	10
22/05/2005	12	6	6
23/05/2005	11	8	3
24/05/2005	14	8	6
25/05/2005	11	5	6
26/05/2005	14	14	0
27/05/2005	12	8	4
28/05/2005	13	12	1
29/05/2005	10	8	2
30/05/2005	13	8	5
31/05/2005	17	12	5
01/06/2005	9	8	1
02/06/2005	11	9	2
03/06/2005	12	11	1
04/06/2005	13	9	4
05/06/2005	12	8	4
06/06/2005	19	12	7
07/06/2005	34	16	18
08/06/2005	27	15	12
09/06/2005	25	10	15
10/06/2005	26	11	15
11/06/2005	33	15	18
12/06/2005	31	7	24
13/06/2005	36	14	22
14/06/2005	17	8	9
15/06/2005	27	10	17
16/06/2005	14	9	5
17/06/2005	15	9	6
18/06/2005	17	12	5
19/06/2005	18	10	8
20/06/2005	17	9	8
21/06/2005	29	9	20
22/06/2005	22	12	10
23/06/2005	16	10	6
24/06/2005	No Data	14	N/A
25/06/2005	No Data	10	N/A
26/06/2005	No Data	11	N/A
27/06/2005	No Data	9	N/A
28/06/2005	No Data	15	N/A
29/06/2005	20	18	2
30/06/2005	21	8	13
01/07/2005	21	13	8
02/07/2005	14	9	5

Date	Monitored Daily mean PM_{10} Concentration at Eglish (µg/m^3)	Monitored Daily Mean PM_{10} Concentration at Lough Navar (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
03/07/2005	12	9	3
04/07/2005	13	11	2
05/07/2005	12	8	4
06/07/2005	17	10	7
07/07/2005	13	9	4
08/07/2005	9	7	2
09/07/2005	9	7	2
10/07/2005	13	8	5
11/07/2005	17	13	4
12/07/2005	28	10	18
13/07/2005	11	7	4
14/07/2005	14	9	5
15/07/2005	20	15	5
16/07/2005	21	13	8
17/07/2005	14	7	7
18/07/2005	14	12	2
19/07/2005	14	10	4
20/07/2005	16	11	5
21/07/2005	16	6	10
22/07/2005	15	6	9
23/07/2005	13	8	5
24/07/2005	19	15	4
25/07/2005	18	10	8
26/07/2005	20	9	11
27/07/2005	22	12	10
28/07/2005	28	13	15
29/07/2005	23	9	14
30/07/2005	30	6	24
31/07/2005	32	7	25
01/08/2005	26	9	17
02/08/2005	26	11	15
03/08/2005	36	15	21
04/08/2005	28	9	19
05/08/2005	46	9	37
06/08/2005	31	9	22
07/08/2005	35	9	26
08/08/2005	39	11	28
09/08/2005	38	6	32
10/08/2005	35	15	20
11/08/2005	33	6	27
12/08/2005	29	7	22
13/08/2005	29	8	21
14/08/2005	26	9	17
15/08/2005	24	10	14
16/08/2005	20	11	9
17/08/2005	20	9	11
18/08/2005	8	8	0
19/08/2005	15	16	0

The estimated contributions of the farm to monitored daily mean PM_{10} concentrations shown in the table above are illustrated graphically in Figure 18 in relation to the number of birds on the farm. Again, it can be seen that the highest PM_{10} concentrations are observed towards the end of each rearing cycle when birds are being removed from the poultry farm.

Figure 18: Estimated Incremental Contribution of Eglish Poultry Farm to PM_{10} Concentrations



Brantry

Given the rural nature of the site, background concentrations were sourced from the Northern Ireland Air website for the Lough Navar rural background monitoring site. Background concentrations were also sourced from the urban background sites at Cookstown, Dungannon Lambfields and Strabane Springhill Park. Comparison of the measured concentrations at the urban background sites to those at Brantry indicated that the urban background concentrations were not representative of background concentrations at Brantry, given that on the majority of days during the survey period, monitored concentrations at the Brantry Farm were below those at these urban background concentrations.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero.

For those days where daily mean PM_{10} concentrations were not available for the Lough Navar site, background PM_{10} concentrations from the Strabane Springhill Park site were used, as this was considered to be the most representative of the three other sites considered for which data were available during these periods. This was only necessary for a total of 44 days during the survey period and in most cases resulted in the assumed contribution being zero. The incremental contribution from Brantry Farm is shown in Table 26.

Table 26: Calculation of Incremental Contribution of Brantry Poultry Farm to PM_{10} Concentrations

Date	Monitored Daily mean PM_{10} Concentration at Brantry (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
28/12/2006	7	15	0
29/12/2006	No Data	8	N/A
30/12/2006	3	8	0
31/12/2006	6	10	0
01/01/2007	5	10	0
02/01/2007	18	21	0
03/01/2007	8	13	0
04/01/2007	15	16	0
05/01/2007	15	12	3
06/01/2007	9	9	0
07/01/2007	9	7	2
08/01/2007	6	8	0
09/01/2007	17	13	4
10/01/2007	12	12	0
11/01/2007	31	31	0
12/01/2007	25	22	3
13/01/2007	15	12	3
14/01/2007	16	15	1
15/01/2007	12	11	1
16/01/2007	16	8	8
17/01/2007	9	8	1
18/01/2007	No Data	19	N/A
19/01/2007	No Data	19	N/A
20/01/2007	8	9	0
21/01/2007	7	10	0
22/01/2007	12	9	3
23/01/2007	No Data	7	N/A
24/01/2007	8	11	0
25/01/2007	5	9	0
26/01/2007	7	11	0
27/01/2007	5	7	0
28/01/2007	8	9	0
29/01/2007	5	7	0
30/01/2007	6	7	0
31/01/2007	10	10	0
01/02/2007	13	10	3
02/02/2007	23	17	6
03/02/2007	31	14	17

Date	Monitored Daily mean PM_{10} Concentration at Brantry ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
04/02/2007	19	13	6
05/02/2007	15	6	9
06/02/2007	No Data	6	N/A
07/02/2007	15	11	4
08/02/2007	14	13	1
09/02/2007	16	14	2
10/02/2007	11	10	1
11/02/2007	13	9	4
12/02/2007	15	11	4
13/02/2007	21	16	5
14/02/2007	23	23	0
15/02/2007	19	13	6
16/02/2007	29	17	12
17/02/2007	20	11	9
18/02/2007	25	10	15
19/02/2007	11	6	5
20/02/2007	23	14	9
21/02/2007	11	7	4
22/02/2007	20	14	6
23/02/2007	20	13	7
24/02/2007	12	9	3
25/02/2007	12	11	1
26/02/2007	16	9	7
27/02/2007	13	10	3
28/02/2007	16	15	1
01/03/2007	15	13	2
02/03/2007	13	9	4
03/03/2007	12	10	2
04/03/2007	16	11	5
05/03/2007	11	9	2
06/03/2007	17	14	3
07/03/2007	17	13	4
08/03/2007	15	13	2
09/03/2007	6	20	0
10/03/2007	21	15	6
11/03/2007	13	10	3
12/03/2007	10	9	1
13/03/2007	20	16	4
14/03/2007	21	15	6
15/03/2007	17	13	4
16/03/2007	21	12	9
17/03/2007	17	15	2
18/03/2007	12	14	0
19/03/2007	No Data	15	N/A
20/03/2007	No Data	9	N/A
21/03/2007	No Data	10	N/A
22/03/2007	No Data	9	N/A
23/03/2007	No Data	10	N/A

Date	Monitored Daily mean PM_{10} Concentration at Brantry (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
24/03/2007	No Data	15	N/A
25/03/2007	50	39	11
26/03/2007	56	40	16
27/03/2007	72	56	16
28/03/2007	20	22	0
29/03/2007	10	7	3
30/03/2007	50	41	9
31/03/2007	48	39	9
01/04/2007	25	18	7
02/04/2007	No Data	23	N/A
03/04/2007	13	18	0
04/04/2007	14	12	2
05/04/2007	12	13	0
06/04/2007	22	17	5
07/04/2007	29	20	9
08/04/2007	17	18	0
09/04/2007	11	13	0
10/04/2007	12	8	4
11/04/2007	14	10	4
12/04/2007	24	19	5
13/04/2007	40	29	11
14/04/2007	41	36	5
15/04/2007	No Data	21	N/A
16/04/2007	No Data	10	N/A
17/04/2007	7	10	0
18/04/2007	11	11	0
19/04/2007	13	9	4
20/04/2007	32	21	11
21/04/2007	28	21	7
22/04/2007	13	8	5
23/04/2007	7	5	2
24/04/2007	9	11	0
25/04/2007	13	17	0
26/04/2007	23	9	14
27/04/2007	42	13	29
28/04/2007	30	16	14
29/04/2007	40	22	18
30/04/2007	37	21	16
01/05/2007	44	20	24
02/05/2007	67	19	48
03/05/2007	51	16	35
04/05/2007	37	17	20
05/05/2007	23	20	3
06/05/2007	15	16	0
07/05/2007	12	12	0
08/05/2007	10	10	0
09/05/2007	10	9	1
10/05/2007	9	9	0

Date	Monitored Daily mean PM_{10} Concentration at Brantry (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
11/05/2007	10	7	3
12/05/2007	10	9	1
13/05/2007	12	9	3
14/05/2007	10	9	1
15/05/2007	11	7	4
16/05/2007	7	7	0
17/05/2007	6	6	0
18/05/2007	12	13	0
19/05/2007	17	16	1
20/05/2007	12	12	0
21/05/2007	12	9	3
22/05/2007	27	30	0
23/05/2007	9	6	3
24/05/2007	6	5	1
25/05/2007	12	11	1
26/05/2007	9	7	2
27/05/2007	15	10	5
28/05/2007	14	9	5
29/05/2007	14	11	3
30/05/2007	No Data	12	N/A
31/05/2007	No Data	11	N/A
01/06/2007	10	15	0
02/06/2007	9	7	2
03/06/2007	12	10	2
04/06/2007	30	14	16
05/06/2007	45	16	29
06/06/2007	49	16	33
07/06/2007	43	18	25
08/06/2007	40	21	19
09/06/2007	40	19	21
10/06/2007	50	21	29
11/06/2007	25	30	0
12/06/2007	25	28	0
13/06/2007	25	7	18
14/06/2007	31	7	24
15/06/2007	32	7	25
16/06/2007	26	8	18
17/06/2007	35	10	25
18/06/2007	21	13	8
19/06/2007	21	16	5
20/06/2007	28	17	11
21/06/2007	18	16	2
22/06/2007	9	9	0
23/06/2007	12	7	5
24/06/2007	14	8	6
25/06/2007	No Data	10	N/A
26/06/2007	11	18	0
27/06/2007	11	10	1

Date	Monitored Daily mean PM_{10} Concentration at Brantry (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
28/06/2007	9	8	1
29/06/2007	15	10	5
30/06/2007	30	11	19
01/07/2007	17	12	5
02/07/2007	9	9	0
03/07/2007	9	9	0
04/07/2007	10	10	0
05/07/2007	10	8	2
06/07/2007	8	9	0
07/07/2007	10	10	0
08/07/2007	9	9	0
09/07/2007	8	8	0
10/07/2007	9	10	0
11/07/2007	14	9	5
12/07/2007	8	10	0
13/07/2007	13	8	5
14/07/2007	9	10	0
15/07/2007	11	11	0
16/07/2007	9	8	1
17/07/2007	11	9	2
18/07/2007	12	9	3
19/07/2007	19	12	7
20/07/2007	24	16	8
21/07/2007	11	10	1
22/07/2007	12	11	1
23/07/2007	19	9	10
24/07/2007	11	8	3
25/07/2007	11	11	0
26/07/2007	9	8	1
27/07/2007	11	11	0
28/07/2007	17	10	7
29/07/2007	11	9	2
30/07/2007	No Data	10	N/A
31/07/2007	No Data	12	N/A
01/08/2007	17	10	7
02/08/2007	15	9	6
03/08/2007	16	9	7
04/08/2007	18	12	6
05/08/2007	35	9	26
06/08/2007	14	11	3
07/08/2007	16	14	2
08/08/2007	16	11	5
09/08/2007	15	9	6
10/08/2007	10	7	3
11/08/2007	11	6	5
12/08/2007	5	6	0
13/08/2007	8	8	0
14/08/2007	No Data	6	N/A

Date	Monitored Daily mean PM_{10} Concentration at Brantry (μg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (μg/m^3)	Estimated Contribution from Poultry Farm (μg/m^3)
15/08/2007	10	9	1
16/08/2007	13	18	0
17/08/2007	14	8	6
18/08/2007	5	7	0
19/08/2007	7	11	0
20/08/2007	9	8	1
21/08/2007	No Data	14	N/A
22/08/2007	No Data	11	N/A
23/08/2007	No Data	9	N/A
24/08/2007	No Data	8	N/A
25/08/2007	No Data	6	N/A
26/08/2007	No Data	12	N/A
27/08/2007	No Data	13	N/A
28/08/2007	No Data	8	N/A
29/08/2007	No Data	12	N/A
30/08/2007	6	10	0
31/08/2007	5	8	0
01/09/2007	6	9	0
02/09/2007	9	9	0
03/09/2007	11	15	0
04/09/2007	12	10	2
05/09/2007	9	8	1
06/09/2007	9	9	0
07/09/2007	10	8	2
08/09/2007	10	10	0
09/09/2007	10	10	0
10/09/2007	18	16	2
11/09/2007	17	16	1
12/09/2007	16	12	4
13/09/2007	20	12	8
14/09/2007	No Data	12	N/A
15/09/2007	No Data	12	N/A
16/09/2007	8	8	0
17/09/2007	10	10	0
18/09/2007	8	8	0
19/09/2007	9	11	0
20/09/2007	12	13	0
21/09/2007	No Data	11	N/A
22/09/2007	No Data	9	N/A
23/09/2007	No Data	12	N/A
24/09/2007	No Data	12	N/A
25/09/2007	No Data	13	N/A
26/09/2007	25	10	15
27/09/2007	32	9	23
28/09/2007	32	11	21
29/09/2007	27	12	15
30/09/2007	31	16	15
01/10/2007	38	18	20

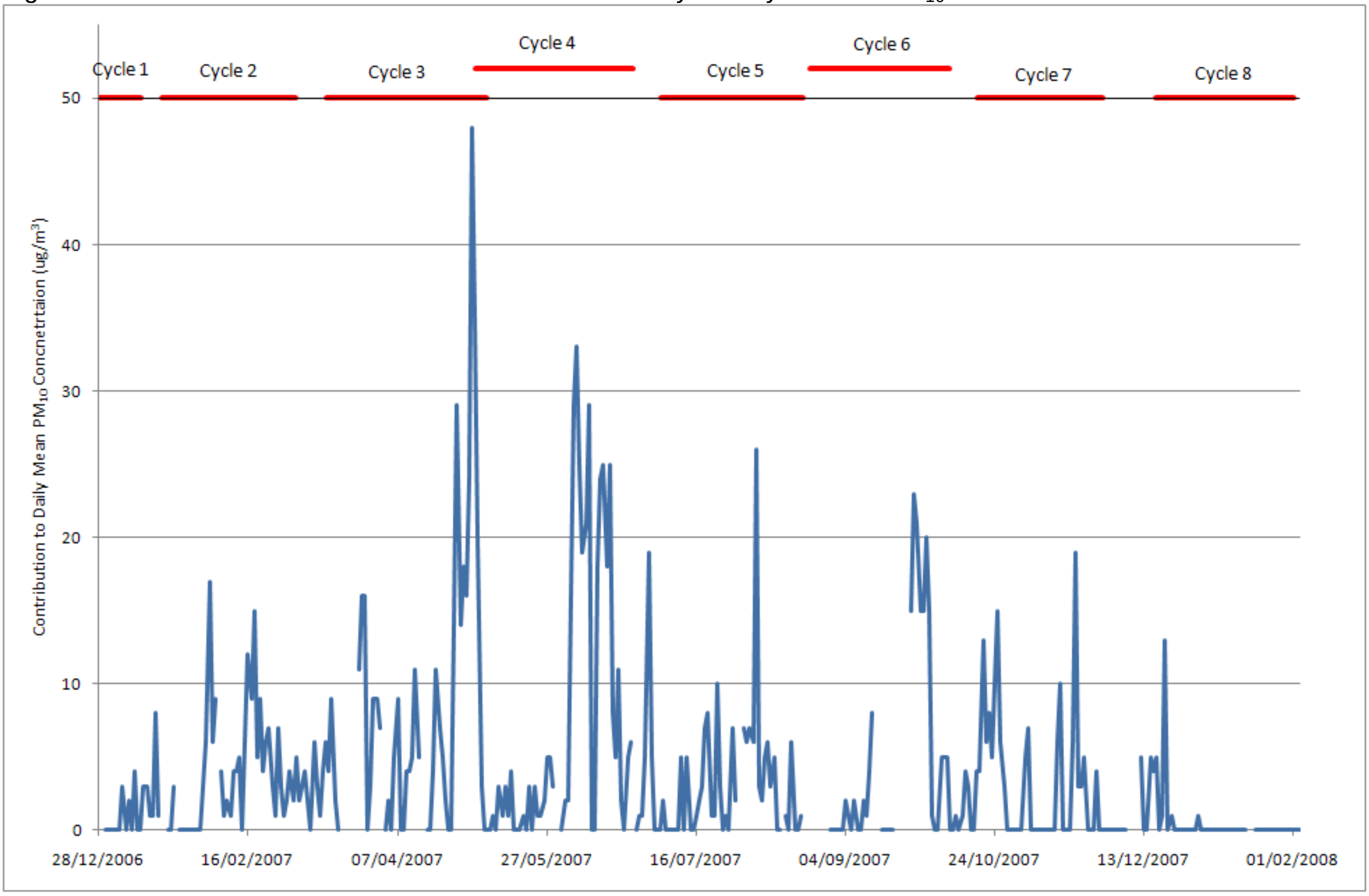
Date	Monitored Daily mean PM_{10} Concentration at Brantry (μg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (μg/m^3)	Estimated Contribution from Poultry Farm (μg/m^3)
02/10/2007	32	17	15
03/10/2007	10	9	1
04/10/2007	6	10	0
05/10/2007	11	11	0
06/10/2007	22	17	5
07/10/2007	23	18	5
08/10/2007	25	20	5
09/10/2007	13	22	0
10/10/2007	13	13	0
11/10/2007	10	9	1
12/10/2007	14	14	0
13/10/2007	15	14	1
14/10/2007	24	20	4
15/10/2007	14	11	3
16/10/2007	8	11	0
17/10/2007	10	12	0
18/10/2007	15	11	4
19/10/2007	17	13	4
20/10/2007	29	16	13
21/10/2007	26	20	6
22/10/2007	22	14	8
23/10/2007	30	25	5
24/10/2007	31	21	10
25/10/2007	31	16	15
26/10/2007	21	15	6
27/10/2007	13	10	3
28/10/2007	6	11	0
29/10/2007	3	19	0
30/10/2007	7	12	0
31/10/2007	19	19	0
01/11/2007	14	14	0
02/11/2007	16	17	0
03/11/2007	24	19	5
04/11/2007	27	20	7
05/11/2007	16	21	0
06/11/2007	17	17	0
07/11/2007	12	16	0
08/11/2007	14	19	0
09/11/2007	16	24	0
10/11/2007	16	22	0
11/11/2007	15	15	0
12/11/2007	10	12	0
13/11/2007	17	27	0
14/11/2007	16	10	6
15/11/2007	22	12	10
16/11/2007	7	13	0
17/11/2007	1	11	0
18/11/2007	5	6	0

Date	Monitored Daily mean PM_{10} Concentration at Brantry (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
19/11/2007	19	13	6
20/11/2007	32	13	19
21/11/2007	17	14	3
22/11/2007	14	11	3
23/11/2007	16	11	5
24/11/2007	12	19	0
25/11/2007	15	18	0
26/11/2007	8	8	0
27/11/2007	10	6	4
28/11/2007	6	6	0
29/11/2007	9	10	0
30/11/2007	5	7	0
01/12/2007	5	11	0
02/12/2007	5	10	0
03/12/2007	5	11	0
04/12/2007	9	10	0
05/12/2007	13	20	0
06/12/2007	11	13	0
07/12/2007	5	12	0
08/12/2007	No Data	10	N/A
09/12/2007	No Data	11	N/A
10/12/2007	No Data	12	N/A
11/12/2007	No Data	11	N/A
12/12/2007	16	11	5
13/12/2007	16	18	0
14/12/2007	19	19	0
15/12/2007	24	19	5
16/12/2007	26	22	4
17/12/2007	25	20	5
18/12/2007	23	24	0
19/12/2007	23	22	1
20/12/2007	38	25	13
21/12/2007	22	26	0
22/12/2007	14	13	1
23/12/2007	6	11	0
24/12/2007	8	10	0
25/12/2007	5	13	0
26/12/2007	9	13	0
27/12/2007	15	22	0
28/12/2007	3	8	0
29/12/2007	2	17	0
30/12/2007	7	10	0
31/12/2007	10	9	1
01/01/2008	10	15	0
02/01/2008	13	19	0
03/01/2008	10	13	0
04/01/2008	8	15	0
05/01/2008	5	28	0

Date	Monitored Daily mean PM_{10} Concentration at Brantry ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
06/01/2008	4	18	0
07/01/2008	3	14	0
08/01/2008	10	15	0
09/01/2008	0	21	0
10/01/2008	3	14	0
11/01/2008	2	14	0
12/01/2008	6	14	0
13/01/2008	1	10	0
14/01/2008	3	16	0
15/01/2008	14	22	0
16/01/2008	15	25	0
17/01/2008	No Data	20	N/A
18/01/2008	No Data	22	N/A
19/01/2008	17	21	0
20/01/2008	12	19	0
21/01/2008	16	17	0
22/01/2008	10	14	0
23/01/2008	11	18	0
24/01/2008	8	21	0
25/01/2008	21	34	0
26/01/2008	14	22	0
27/01/2008	14	24	0
28/01/2008	17	20	0
29/01/2008	7	16	0
30/01/2008	4	14	0
31/01/2008	8	30	0
01/02/2008	11	32	0
02/02/2008	4	11	0
03/02/2008	6	14	0

The estimated contributions of the farm to monitored daily mean PM_{10} concentrations shown in the table above are illustrated graphically in Figure 19 in relation to the dates of the rearing cycles at the farm. It can be seen that the highest PM_{10} concentrations are observed towards the end of each rearing cycle.

Figure 19: Estimated Incremental Contribution of Brantry Poultry Farm to PM_{10} Concentrations



Pen Lon

Background concentrations were sourced from the Defra website for the Blackpool urban background monitoring site, located approximately 110 km north-east of the Pen Lon site. Background concentrations were also sourced from the rural background site at Narberth; however, there was no data for this site for a significant duration of the monitoring period. Where data was available, it was comparable to the Blackpool data.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero. The incremental contribution from Pen Lon Farm is shown in Table 27.

Table 27: Calculation of Incremental Contribution of Pen Lon Poultry Farm to PM_{10} Concentrations

Date	Monitored Daily Mean PM_{10} Concentration at Pen Lon ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
20/06/2003	23	21	2
21/06/2003	23	20	3
22/06/2003	36	27	9

Date	Monitored Daily Mean PM_{10} Concentration at Pen Lon (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
23/06/2003	23	22	1
24/06/2003	24	17	7
25/06/2003	32	28	4
26/06/2003	27	32	0
27/06/2003	12	19	0
28/06/2003	12	13	0
29/06/2003	20	17	3
30/06/2003	13	12	1
01/07/2003	12	13	0
02/07/2003	17	19	0
03/07/2003	13	18	0
04/07/2003	15	20	0
05/07/2003	12	14	0
06/07/2003	12	12	0
07/07/2003	15	16	0
08/07/2003	17	15	2
09/07/2003	16	18	0
10/07/2003	18	18	0
11/07/2003	23	22	1
12/07/2003	25	24	1
13/07/2003	25	33	0
14/07/2003	No Data	35	N/A
15/07/2003	44	41	3
16/07/2003	51	40	11
17/07/2003	28	21	7
18/07/2003	22	13	9
19/07/2003	37	23	14
20/07/2003	33	16	17
21/07/2003	30	16	14
22/07/2003	21	15	6
23/07/2003	29	13	16
24/07/2003	17	13	4
25/07/2003	18	12	6
26/07/2003	23	12	11
27/07/2003	25	15	10
28/07/2003	39	18	21
29/07/2003	30	13	17
30/07/2003	15	18	0
31/07/2003	33	14	19
01/08/2003	33	17	16
02/08/2003	43	25	18
03/08/2003	33	26	7
04/08/2003	29	31	0
05/08/2003	53	44	9
06/08/2003	42	32	10
07/08/2003	48	32	16
08/08/2003	43	36	7
09/08/2003	70	58	12

Date	Monitored Daily Mean PM_{10} Concentration at Pen Lon (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
10/08/2003	35	26	9
11/08/2003	22	16.0	6
12/08/2003	20	16.6	3
13/08/2003	30	No Data	0
14/08/2003	22	No Data	0
15/08/2003	19	22	0
16/08/2003	35	42	0
17/08/2003	76	26	50
18/08/2003	33	21	12
19/08/2003	24	22	2
20/08/2003	37	19	18
21/08/2003	39	29	10
22/08/2003	31	14	17
23/08/2003	34	13	21
24/08/2003	19	22	0
25/08/2003	22	15	7
26/08/2003	18	17	1
27/08/2003	25	20	5
28/08/2003	23	24	0
29/08/2003	13	16	0
30/08/2003	No Data	14	N/A
31/08/2003	No Data	13	N/A
01/09/2003	18	19	0
02/09/2003	13	14	0
03/09/2003	10	20	0
04/09/2003	19	34	0
05/09/2003	22	44	0
06/09/2003	12	13	0
07/09/2003	10	17	0
08/09/2003	8	14	0
09/09/2003	13	21	0
10/09/2003	11	14	0
11/09/2003	15	26	0
12/09/2003	20	33	0
13/09/2003	28	30	0
14/09/2003	28	27	1
15/09/2003	29	36	0
16/09/2003	28	38	0
17/09/2003	33	34	0
18/09/2003	27	No Data	0
19/09/2003	22	5	17
20/09/2003	11	5	6
21/09/2003	29	17	12
22/09/2003	16	19	0
23/09/2003	16	19	0
24/09/2003	23	18	5
25/09/2003	36	27	9
26/09/2003	21	23	0

Date	Monitored Daily Mean PM_{10} Concentration at Pen Lon (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
27/09/2003	15	21	0
28/09/2003	19	12	7
29/09/2003	20	15	5
30/09/2003	33	28	5
01/10/2003	25	35	0
02/10/2003	25	38	0
03/10/2003	22	31	0
04/10/2003	14	21	0
05/10/2003	14	15	0
06/10/2003	25	40	0
07/10/2003	21	39	0
08/10/2003	18	26	0
09/10/2003	29	32	0
10/10/2003	25	36	0
11/10/2003	44	33	11
12/10/2003	37	24	13
13/10/2003	19	31	0
14/10/2003	29	29	0

Cubley

Background concentrations were sourced from the Defra website for the Harwell rural background monitoring site, located approximately 150 km south of the Cubley site. Background concentrations were also sourced from the urban background sites at Chesterfield and Birmingham, however, monitored concentrations at these locations were significantly above those at Cubley on the majority of days, suggesting they are not representative of background concentrations in Cubley.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero. The incremental contribution from Cubley Farm is shown in Table 28.

Table 28: Calculation of Incremental Contribution of Cubley Farm to PM_{10} Concentrations

Date	Monitored Daily mean PM_{10} Concentration at Cubley (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
01/12/2010	10	16	0
02/12/2010	12	10	2
03/12/2010	29	12	17
04/12/2010	21	8	13
05/12/2010	21	8	13
06/12/2010	33	12	21
07/12/2010	42	14	28
08/12/2010	17	16	1
09/12/2010	15	8	7
10/12/2010	16	6	10
11/12/2010	15	6	9
12/12/2010	15	19	0

Date	Monitored Daily mean PM_{10} Concentration at Cubley (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
13/12/2010	16	14	2
14/12/2010	16	16	0
15/12/2010	14	12	2
16/12/2010	12	5	7
17/12/2010	16	6	10
18/12/2010	22	12	10
19/12/2010	28	17	11
20/12/2010	34	20	14
21/12/2010	30	27	3
22/12/2010	25	21	4
23/12/2010	19	12	7
24/12/2010	19	16	3
25/12/2010	22	16	6
26/12/2010	29	8	21
27/12/2010	23	12	11
28/12/2010	21	6	15
29/12/2010	21	9	12
30/12/2010	25	11	14
31/12/2010	26	15	11
01/01/2011	14	12	2
02/01/2011	10	12	0
03/01/2011	20	20	0
04/01/2011	16	No Data	0
05/01/2011	18	No Data	0
06/01/2011	16	No Data	0
07/01/2011	13	No Data	0
08/01/2011	14	No Data	0
09/01/2011	8	No Data	0
10/01/2011	No Data	No Data	0
11/01/2011	14	No Data	0
12/01/2011	19	No Data	0
13/01/2011	No Data	No Data	0
14/01/2011	No Data	No Data	0
15/01/2011	No Data	No Data	0
16/01/2011	No Data	No Data	0
17/01/2011	No Data	No Data	0
18/01/2011	17	No Data	0
19/01/2011	18	No Data	0
20/01/2011	20	No Data	0
21/01/2011	23	24	0
22/01/2011	22	24	0
23/01/2011	19	18	1
24/01/2011	21	12	9
25/01/2011	21	7	14
26/01/2011	15	9	6
27/01/2011	14	6	8
28/01/2011	18	11	7
29/01/2011	18	20	0

Date	Monitored Daily mean PM_{10} Concentration at Cubley (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
30/01/2011	12	11	1

Fleet Fen

Background concentrations were sourced from the South Holland DC Air website[47] for the Spalding Monkhouse and Westmere School sites. An average of the monitored concentrations at these sites was used which was the same methodology employed in the South Holland DC Detailed Assessment.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero. The incremental contribution from Fleet Fen Farm is shown in Table 29.

Table 29: Calculation of Incremental Contribution of Fleet Fen Farm to PM_{10} Concentrations

Date	Monitored Daily mean PM_{10} Concentration at Fleet Fen Moulton (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
10/09/2010	21	17	4
11/09/2010	19	14	5
12/09/2010	14	10	4
13/09/2010	17	16	1
14/09/2010	16	12	4
15/09/2010	15	11	4
16/09/2010	13	9	4
17/09/2010	12	11	1
18/09/2010	10	10	0
19/09/2010	14	10	4
20/09/2010	17	11	6
21/09/2010	22	20	2
22/09/2010	22	23	0
23/09/2010	13	11	2
24/09/2010	14	8	6
25/09/2010	10	8	2
26/09/2010	15	9	5
27/09/2010	27	15	12
28/09/2010	36	26	10
29/09/2010	21	14	8
30/09/2010	18	12	6
01/10/2010	14	10	4
02/10/2010	20	14	6
03/10/2010	12	11	1
04/10/2010	13	13	0
05/10/2010	23	15	8
06/10/2010	18	11	7
07/10/2010	24	18	7
08/10/2010	51	43	8
09/10/2010	50	41	9
10/10/2010	48	37	12

Date	Monitored Daily mean PM_{10} Concentration at Fleet Fen Moulton (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
11/10/2010	30	26	4
12/10/2010	15	14	1
13/10/2010	15	12	2
14/10/2010	28	18	10
15/10/2010	25	16	10
16/10/2010	15	13	2
17/10/2010	21	15	6
18/10/2010	24	17	7
19/10/2010	21	12	9
20/10/2010	19	9	10
21/10/2010	16	10	5
22/10/2010	12	11	0
23/10/2010	17	9	7
24/10/2010	14	8	6
25/10/2010	18	14	4
26/10/2010	16	12	4
27/10/2010	23	14	9
28/10/2010	23	14	8
29/10/2010	23	16	6
30/10/2010	18	11	7
31/10/2010	27	17	10
01/11/2010	35	25	10
02/11/2010	35	19	16
03/11/2010	18	11	7
04/11/2010	11	11	0
05/11/2010	18	15	3
06/11/2010	31	34	0
07/11/2010	29	27	2
08/11/2010	14	12	2
09/11/2010	12	7	6
10/11/2010	20	9	11
11/11/2010	17	11	6
12/11/2010	21	11	10
13/11/2010	16	11	5
14/11/2010	28	15	13
15/11/2010	25	19	6
16/11/2010	30	24	6
17/11/2010	34	24	10
18/11/2010	27	19	8
19/11/2010	20	14	6
20/11/2010	20	15	6
21/11/2010	13	9	4
22/11/2010	15	10	5
23/11/2010	25	10	15
24/11/2010	28	12	16
25/11/2010	19	10	9
26/11/2010	28	16	12
27/11/2010	16	12	5

Date	Monitored Daily mean PM_{10} Concentration at Fleet Fen Moulton ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
28/11/2010	33	20	13
29/11/2010	22	16	6
30/11/2010	13	10	3
01/12/2010	16	17	0
02/12/2010	17	13	4
03/12/2010	29	22	7
04/12/2010	18	15	3
05/12/2010	39	18	21
06/12/2010	41	29	12
07/12/2010	49	35	14
08/12/2010	28	15	13
09/12/2010	33	13	20
10/12/2010	29	15	14
11/12/2010	35	14	21
12/12/2010	31	18	14
13/12/2010	32	19	13
14/12/2010	32	17	14
15/12/2010	25	17	8
16/12/2010	19	11	8
17/12/2010	22	12	10
18/12/2010	20	18	2
19/12/2010	27	22	6
20/12/2010	26	26	0
21/12/2010	30	27	3
22/12/2010	18	23	0
23/12/2010	18	18	0
24/12/2010	25	17	7
25/12/2010	28	22	6
26/12/2010	28	26	3
27/12/2010	22	18	4
28/12/2010	27	19	8
29/12/2010	19	22	0
30/12/2010	25	25	1
31/12/2010	41	29	12
01/01/2011	29	16	12
02/01/2011	22	10	12
03/01/2011	28	23	5
04/01/2011	25	18	7
05/01/2011	16	11	5
06/01/2011	26	17	9
07/01/2011	23	18	5
08/01/2011	19	13	6
09/01/2011	16	11	5
10/01/2011	18	15	2
11/01/2011	24	11	13
12/01/2011	17	12	4
13/01/2011	28	9	19
14/01/2011	18	12	6

Date	Monitored Daily mean PM_{10} Concentration at Fleet Fen Moulton ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
15/01/2011	24	16	8
16/01/2011	20	13	7
17/01/2011	21	22	0
18/01/2011	33	20	12
19/01/2011	34	20	14
20/01/2011	29	21	8
21/01/2011	39	30	9
22/01/2011	28	22	6
23/01/2011	28	21	7
24/01/2011	24	17	6
25/01/2011	25	17	8
26/01/2011	15	13	2
27/01/2011	10	12	0
28/01/2011	14	14	0
29/01/2011	15	17	0
30/01/2011	12	17	0
31/01/2011	43	40	4
01/02/2011	27	26	1
02/02/2011	17	19	0
03/02/2011	16	17	0
04/02/2011	14	15	0
05/02/2011	13	11	1
06/02/2011	12	11	0
07/02/2011	17	14	2
08/02/2011	22	17	4
09/02/2011	33	31	2
10/02/2011	22	22	0
11/02/2011	23	21	1
12/02/2011	27	27	0
13/02/2011	19	18	0
14/02/2011	11	14	0
15/02/2011	20	15	5
16/02/2011	23	15	8
17/02/2011	35	24	11
18/02/2011	53	41	12
19/02/2011	56	40	16
20/02/2011	54	45	9
21/02/2011	59	48	10
22/02/2011	52	46	6
23/02/2011	28	23	5
24/02/2011	23	16	7
25/02/2011	21	14	7
26/02/2011	17	8	10
27/02/2011	18	11	8
28/02/2011	27	19	8
01/03/2011	16	16	0
02/03/2011	34	31	4
03/03/2011	23	18	5

Date	Monitored Daily mean PM_{10} Concentration at Fleet Fen Moulton (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
04/03/2011	21	18	2
05/03/2011	26	24	2
06/03/2011	21	20	1
07/03/2011	23	23	1
08/03/2011	43	42	1
09/03/2011	20	16	3
10/03/2011	19	18	1
11/03/2011	15	17	0
12/03/2011	25	22	3
13/03/2011	33	21	12
14/03/2011	20	18	2
15/03/2011	48	27	21
16/03/2011	51	38	14

Great Moulton

Background concentrations were sourced from the South Holland DC Air website[48] for the Spalding Monkhouse and Westmere School sites, located approximately 100 km west of the Great Moulton farm. An average of the monitored concentrations at these sites was used which was the same methodology employed in the South Holland Detailed Assessment.

Where the estimated contribution from the poultry farm was negative, i.e. monitored background concentrations were higher than those measured at the farm the increment from the poultry farm was assumed to be zero. The incremental contribution from Great Moulton Farm is shown in Table 30.

Table 30: Calculation of Incremental Contribution of Great Moulton Farm to PM_{10} Concentrations

Date	Monitored Daily mean PM_{10} Concentration at Great Moulton (µg/m^3)	Monitored Daily Mean Background PM_{10} Concentration (µg/m^3)	Estimated Contribution from Poultry Farm (µg/m^3)
23/07/2005	25	21	4
24/07/2005	22	14	9
25/07/2005	24	9	14
26/07/2005	12	11	1
27/07/2005	18	11	7
28/07/2005	29	19	10
29/07/2005	27	15	12
30/07/2005	16	12	4
31/07/2005	14	14	0
01/08/2005	22	17	5
02/08/2005	29	20	9
03/08/2005	21	15	5
04/08/2005	21	19	2
05/08/2005	15	12	3
06/08/2005	20	13	7
07/08/2005	17	12	5
08/08/2005	18	19	0

Date	Monitored Daily mean PM_{10} Concentration at Great Moulton ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
09/08/2005	25	18	7
10/08/2005	39	18	21
11/08/2005	21	17	4
12/08/2005	23	16	7
13/08/2005	17	13	4
14/08/2005	17	14	3
15/08/2005	16	16	0
16/08/2005	27	15	12
17/08/2005	33	27	7
18/08/2005	57	29	28
19/08/2005	37	13	24
20/08/2005	19	14	5
21/08/2005	26	15	11
22/08/2005	17	13	4
23/08/2005	25	16	9
24/08/2005	16	11	5
25/08/2005	12	10	3
26/08/2005	18	10	7
27/08/2005	19	12	7
28/08/2005	24	15	10
29/08/2005	29	14	15
30/08/2005	44	20	25
31/08/2005	54	30	24
01/09/2005	28	17	10
02/09/2005	24	14	10
03/09/2005	37	23	14
04/09/2005	25	27	0
05/09/2005	42	23	19
07/09/2005	21	17	4
08/09/2005	23	14	9
09/09/2005	36	22	15
10/09/2005	16	10	6
11/09/2005	18	15	3
12/09/2005	12	12	1
13/09/2005	17	19	0
14/09/2005	19	14	5
23/09/2005	21	23	0
24/09/2005	16	14	2
25/09/2005	15	11	4
26/09/2005	15	11	4
27/09/2005	16	15	1
28/09/2005	15	14	1
29/09/2005	14	13	1
30/09/2005	22	9	13
01/10/2005	11	10	0
02/10/2005	13	9	4
03/10/2005	32	17	15
04/10/2005	34	16	18

Date	Monitored Daily mean PM_{10} Concentration at Great Moulton ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
05/10/2005	28	14	13
06/10/2005	42	29	13
07/10/2005	56	35	21
08/10/2005	40	28	13
09/10/2005	10	8	1
10/10/2005	30	21	8
11/10/2005	36	27	9
12/10/2005	27	21	6
13/10/2005	12	8	4
14/10/2005	30	11	19
15/10/2005	59	30	29
16/10/2005	60	30	31
17/10/2005	62	29	33
18/10/2005	31	19	11
19/10/2005	17	13	4
20/10/2005	14	10	3
21/10/2005	15	10	5
22/10/2005	13	11	2
23/10/2005	16	13	3
24/10/2005	14	7	8
25/10/2005	13	13	0
26/10/2005	29	20	9
27/10/2005	22	18	4
28/10/2005	17	14	3
29/10/2005	14	12	3
30/10/2005	24	16	8
31/10/2005	13	15	0
01/11/2005	13	12	1
02/11/2005	16	11	5
03/11/2005	22	13	8
04/11/2005	15	12	3
05/11/2005	26	17	9
06/11/2005	19	10	9
07/11/2005	17	14	2
08/11/2005	26	15	11
09/11/2005	21	12	8
10/11/2005	25	10	15
11/11/2005	8	8	0
12/11/2005	15	13	1
13/11/2005	19	14	5
14/11/2005	15	13	2
15/11/2005	15	11	3
16/11/2005	10	10	0
17/11/2005	19	13	6
18/11/2005	23	21	2
19/11/2005	21	24	0
20/11/2005	26	23	3
21/11/2005	25	31	0

Date	Monitored Daily mean PM_{10} Concentration at Great Moulton ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
22/11/2005	22	27	0
23/11/2005	16	23	0
24/11/2005	17	11	6
25/11/2005	9	8	1
26/11/2005	11	11	1
27/11/2005	9	9	0
28/11/2005	13	8	4
29/11/2005	14	14	0
30/11/2005	24	20	5
01/12/2005	18	12	5
02/12/2005	18	13	5
03/12/2005	11	9	2
04/12/2005	13	11	2
05/12/2005	15	11	4
06/12/2005	15	12	2
07/12/2005	16	15	1
08/04/2006	7	11	0
13/04/2006	18	14	4
14/04/2006	19	16	3
15/04/2006	37	15	22
16/04/2006	21	13	8
17/04/2006	15	12	3
18/04/2006	24	16	8
19/04/2006	22	10	12
20/04/2006	18	10	9
21/04/2006	17	14	3
22/04/2006	13	12	1
23/04/2006	24	15	9
24/04/2006	22	14	7
25/04/2006	27	19	8
26/04/2006	24	24	1
27/04/2006	19	19	0
28/04/2006	17	18	0
29/04/2006	12	12	0
30/04/2006	13	9	4
01/05/2006	15	9	6
02/05/2006	22	15	7
03/05/2006	25	17	8
04/05/2006	39	28	11
05/05/2006	23	19	4
07/05/2006	30	19	11
08/05/2006	33	23	10
09/05/2006	30	31	0
10/05/2006	28	22	6
11/05/2006	29	17	12
12/05/2006	34	25	9
13/05/2006	25	15	10
14/05/2006	11	10	1

Date	Monitored Daily mean PM_{10} Concentration at Great Moulton ($\mu g/m^3$)	Monitored Daily Mean Background PM_{10} Concentration ($\mu g/m^3$)	Estimated Contribution from Poultry Farm ($\mu g/m^3$)
15/05/2006	24	15	9
16/05/2006	14	12	2
17/05/2006	18	13	5
18/05/2006	13	11	1
19/05/2006	13	8	5
20/05/2006	12	8	3
21/05/2006	12	10	2
24/05/2006	16	8	7
25/05/2006	15	13	2
26/05/2006	21	11	11
27/05/2006	13	8	5
28/05/2006	10	11	0
29/05/2006	12	9	3
30/05/2006	17	9	8
31/05/2006	16	12	3
01/06/2006	26	11	15
02/06/2006	23	17	6
03/06/2006	31	14	17
04/06/2006	30	15	16
05/06/2006	43	13	31
06/06/2006	22	17	4
07/06/2006	46	22	24
08/06/2006	28	21	6
09/06/2006	35	22	13
10/06/2006	35	25	10
11/06/2006	36	24	12
12/06/2006	35	26	9
13/06/2006	25	16	9
14/06/2006	12	18	0
15/06/2006	14	11	3
16/06/2006	25	19	5
17/06/2006	32	22	11
18/06/2006	31	21	10
19/06/2006	17	14	3
20/06/2006	18	14	4
21/06/2006	20	16	4
22/06/2006	17	15	1
23/06/2006	24	15	9
24/06/2006	26	22	4
25/06/2006	30	24	6
26/06/2006	15	12	3
27/06/2006	15	11	4
28/06/2006	14	14	0

Appendix C: Terminology

Barn	Laying hens are also kept in non-cage housing systems. What these housing systems all have in common is that the birds have more space or can move around more freely within the building.
Breeder	Mature chickens from which fertile eggs are collected.
Broiler	Type of chicken raised specifically for meat production.
Cages	In poultry farming, cages are an industrial agricultural confinement system used primarily for egg-laying hens.
Growing Pullets	Term used for hen from birth until it is moved to the laying flock.
Free Range	This term refers to animals (usually poultry, and the eggs that they produce) that are not confined, meaning that these animals are able to go outdoors to engage in natural behaviours. It does not necessarily mean that the products are cruelty-free or antibiotic-free, or that the animals spend the majority of their time outdoors.
Layer / laying bird	Mature female chicken kept for egg production; also called laying hen.
Litter	Material scattered on the floor of a chicken coop to absorb moisture and manure. Commonly used are straw, hay, pine or other wood shavings or shredded paper, etc. Also called 'bedding'.
Perchery	Birds are kept in large groups and enjoy freedom of movement over the entire house area. Housing space is subdivided into different functional areas (feeding and drinking, sleeping and resting, scratch area, egg laying area). The birds can use several house levels that allow for higher stocking densities.

Capabilities on project:
Environment

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Capabilities on project:
Environment

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