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Odour and ammonia emissions from intensive poultry units in Ireland

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Abstract

Odour and ammonia emissions were measured from three broiler, two layer and two turkey houses in Ireland. The broiler units gave a large range of odour and ammonia emission rates depending on the age of the birds and the season. A considerable variation between the odour and ammonia emission rates was evident for the two layer units which may be due to the different manure handling systems utilised in the houses. There was relatively little difference in the odour and ammonia emissions from the two turkey houses. As a precautionary principle, odour emission rates utilised in atmospheric dispersion models should use the maximum values for broilers and turkeys (1.22 and $10.5 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$ respectively) and the mean value for the layers depending on the manure handling system used (0.47 or $1.35 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$).

Keywords: Poultry, Odour, Ammonia, Olfactometry, House design

1. Introduction

Integrated Pollution Control Licensing (IPC) for pig and poultry production was introduced in Ireland in 1996 and the related guidance note was termed BATNEEC

(Best Available Technology Not Entailing Excessive Cost) (EPA, 1996). It set out specific conditions to be implemented in order to comply with the environmental requirements of the Irish Environmental Protection Agency (EPA). Minimisation of odour emissions and complaints is one of the requirements of the BATNEEC Guidance Note for intensive pig and poultry production units. In order to comply with this requirement, it is recommended that pig and poultry units should be sited at least 400 metres from any odour sensitive location (e.g. dwelling house, church, school).

As a result of a European Union Council Directive (96/61/EC) on Integrated Pollution Prevention and Control (IPPC), each European Union Member State must prepare and implement a best available techniques (BAT) note. It is expected that the BAT note will be implemented fully for existing production units by 2007. At the present time, there are only three poultry units licensed by the EPA in Ireland. An estimated 140 broiler farms in Ireland with capacity over 40,000 birds will be covered by IPPC (European IPPC Bureau, 2002); the limit would be significantly lower than the current IPC figure of 100,000 units (Table 1).

The BAT Reference (BREF) document (European IPPC Bureau, 2002) was published to address the main issues in implementing the IPPC directive. When dealing with atmospheric emissions, BREF is concerned not only with odour but also with ammonia and other gases. Numerous management aspects for broilers, layers and turkey production can influence the generation of odour and ammonia emissions. These include the management of the litter material, the depth of bedding, the type and management of the water and feed supplies, ventilation and temperature control systems, stocking density, animal health and diet quality.

Due to the lack of available data on odour and ammonia emission rates from intensive poultry systems in Ireland and the large variability in published emission rates, it was considered timely to address this issue. This study is part of a larger research program dealing with odour and ammonia emissions from pig and poultry units; a previous paper was devoted to gaseous emissions from pig production systems (Hayes et al., 2005).

2. Materials and methods

2.1. Description of the poultry units

Odour and ammonia measurements were taken on three broiler units (B1, B2, B3), two layer units (L1, L2) and two turkey units (T1, T2) over a two year period. The units selected were typical of the most common designs utilised throughout the European Union. A detailed description of the units studied can be found in Table 2.

The broiler units comprised an approximately equal number of pullets and cocks in a single house separated by a mesh divide. They were reared from day olds until they reached slaughter weight (1.5-2.5 kg). This weight was usually achieved from crop day 35. All the litter was then removed from the house and taken off site for composting. The house was power washed, disinfected and a new litter bed, wood shavings at 5-15 cm depth, was put in ready for the next batch of birds.

The two layer units had distinctly different management systems. Unit L1 housed birds in a battery system of cages four tiers high. The manure from the birds was removed from the house on a mechanical belt system into an underground storage pit

located outside of the house. Unit L2 was a deep litter, slatted floor system. The birds had 24 hour access to a scratching area and weather permitting were allowed outdoors every day. The ventilation in both units was regulated with temperature controlled variable speed fans. The eggs from both units were collected daily on an automated belt system. The birds in both units were replaced once/twice a year.

The turkey units reared stags only. They were reared from six weeks old until they reached slaughter weight. The slaughter weight depended on the market requirements. They were slaughtered at 12-14 weeks for the whole-bird market (6-8 kg) and approximately 20 weeks for the processing market (12-13 kg) (McDougal, 2004). All the litter was removed from the house and taken off site for composting. The house was power washed, disinfected and a new litter bed, wood shavings at 15-20 cm depth, was put in ready for the next batch of birds.

2.2. Measurement of ventilation rates

To determine the ventilation rate from the livestock buildings, a series of equations were used based on animal activity, heat production and carbon dioxide production (CIGR, 2002). CO₂ was measured using a 2 channel infrared absorption CO₂ probe (TESTO, UK) both inside and outside the buildings. The probe has a measurement range of 0-10000 ppm at 1 ppm increments. It is accurate to $\pm 0.01\%$. While the odour samples and ammonia concentrations were being collected, the CO₂ probe was placed at random locations in the building over a known time period to determine the mean internal CO₂ concentration. The CO₂ probe was calibrated at regular intervals by the suppliers.

1.2. Olfactometry

1.2.1. Collection of odour samples

The odour samples were collected in 40 litre Nalophan bags using a battery-powered vacuum pump and a rigid container. The samples were collected using the lung principle whereby the air was removed from the rigid container using a battery-powered vacuum pump at a rate of approximately 4 litres per minute (Rietschle Thomas, WI, USA). A critical orifice controlled the air evacuation rate from the sampling container. This created a vacuum in the rigid container and caused the Nalophan bag to fill through stainless steel tubing with odorous air extracted from the exhaust vents. The odour samples were sealed and stored in appropriate conditions. All the samples were analysed within 24 hours. The odour measurements were carried out according to the European Standard EN13725 (CEN, 2003) in the olfactometry laboratory in the Department of Biosystems Engineering, University College Dublin. Due to constraints in resources and time, no ambient odour measurements were taken in the vicinity of the units. The method assumed that ambient concentrations of odour were zero.

1.2.2. Measurement of odour threshold concentration

An ECOMA TO7 dynamic olfactometer (ECOMA, Honigsee, Germany) was used to measure the odour threshold concentration of the ventilated air from the seven poultry production units. The odour threshold concentration is defined as the dilution factor at which 50% of the panellists can just detect an odour. The panellists were previously selected by screening using the certified reference gas n-butanol (CAS 71-36-3). Only panellists who adhered to the code of behaviour for olfactometry were selected. The odour threshold concentration was calculated according to the response of four panel

members and was displayed in $\text{ou}_E \text{ m}^{-3}$. This refers to the physiological response from the panel equivalent to that elicited by 40 ppbv *n*-butanol evaporated in 1 m^3 of neutral gas (CEN, 2003). Odour units were considered a dimensionless unit, but pseudo-dimensions of $\text{ou}_E \text{ m}^{-3}$ have been commonly used for odour dispersion modelling in place of g m^{-3} (McGinley et al., 2000).

1.3. Measurement of ammonia concentration

Ammonia measurements were taken using an iTX Multi-gas monitor fitted with a biased sensor (iTX Multi-gas Monitor, ISC, PA, USA). The biased sensor has a measurement range of 0-999 ppm, in 1 ppm increments. The sensor was set to take readings every five minutes over the duration of its placement within each house type; these were data logged. The ammonia sensor was placed at random locations within the house, always within close proximity to the ventilation system exhaust outlet. The iTX was calibrated at regular intervals by the suppliers. The iTX provided a simple and easy way of measuring ammonia. It was designed for on-the-spot measurement for health and safety and for continuous measurement over time. As with odour samples, due to constraints in resources and time, no ambient ammonia measurements were taken in the vicinity of the units. The method assumed that ambient concentrations of ammonia were zero.

1.4. Statistical analysis

All statistical analysis was carried out according to Wheater and Cook (2000). Statistical values were calculated using the software package Microsoft ExcelTM.

1.5. Overview of measurement plan

Table 3 illustrates an overview of the measurement plan outlining the measured parameters, the measurement methods and units, and the time scale involved.

3. Results and discussion

3.1. Odour and ammonia results

Odour emission rates per bird ($\text{ou}_E \text{ s}^{-1} \text{ bird}^{-1}$), odour emission rates per kilogram liveweight ($\text{ou}_E \text{ s}^{-1} \text{ kg}^{-1}$), ammonia concentrations (ppm), and ammonia emission rates per bird ($\text{g d}^{-1} \text{ bird}^{-1}$) were calculated to allow standardisation and comparison between the production units and published results. The values reported in this study may be regarded as mean emission values for mean conditions of animal growth and manure handling.

3.2 Broiler results

The odour samples from the three broiler units were collected on six to eight random days over a three-week period towards the end of the growing period for each crop (batch) of birds. This three-week period was chosen as an extended collection period at the first broiler unit (i.e. from the beginning of the crop of birds) found little to odour concentrations within the house. This may be due to the cleanliness of the house at the beginning of crop and low manure production of the smaller birds. The odour emission rates from the three units were plotted to illustrate the temporal variation within the house type and the relationship between crop day and odour emission rate (Figure 1). Linear regression analysis was used to determine the relationship between the odour emission rate and crop day throughout the three-week

sampling period only. Using linear regression analysis, when the odour emission rate is plotted against crop day the following relationship (Eq. 1) can be formed.

$$\text{Equation 1. Odour emission rate} = 0.0409 (\text{Crop day}) - 0.4432$$

The mean odour emission rates for B1, B2 and B3 can be found in Table 4. It should be noted that the odour samples and ammonia monitoring for each of the three units were taken over a different period of crop days and seasons (Crop days 12-35, 19-35 and 22-36 for units B1, B2 and B3 respectively) due to the availability of access to the production units. Ogink and Groot Koerkamp (2001) reported lower ranges of odour emission rates ($0.06 - 0.41 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$) for similar broiler housing systems in the Netherlands. Clarkson and Misselbrook (1991) carried out a study on two broiler houses in the UK and found a range of odour emission rates of 0.35 to $1.6 (\text{ou}_E \text{ s}^{-1} \text{ bird}^{-1})$ for birds at 17 – 45 days old respectively. Robertson et al. (2000) reported UK odour emissions from broilers in the range $20,000$ - $33,000 \text{ ou}_E \text{ s}^{-1}$ for a $34,000$ -bird flock. This represents an odour emission rate of 0.6 - $1.0 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$. The highest odour emission rate per bird ($1.22 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$) should be used when establishing the odour impact area using dispersion models, as this would illustrate the worst-case scenario. However, this approach should be taken as a precautionary principle until a full, detailed and accurate odour emission rate database becomes available.

An important factor in the production of odour and ammonia emissions from this design of broiler unit is the litter. The mean moisture content of the litter in the broiler houses was 35-50% depending on crop day. To minimise the generation of odours and ammonia, damp litter must be avoided; this can be facilitated by the correct choice

and maintenance of the drinking system, shortening the length of the growing period and the correct stocking density (European Commission, 2000). Mean ammonia emission rates of 0.16, 0.30 and 0.50 g d⁻¹ bird⁻¹ were measured for B1, B2 and B3 respectively (Table 5). Seasonal effects and the crop day period when the monitoring took place could explain the variation in the results. The BREF document (European IPPC Bureau, 2002) reported a similar range of ammonia emission rates of 0.014 – 0.86 g d⁻¹ bird⁻¹.

3.3 Layer unit results

The odour samples from the two layer units were collected on six random days over a three-week period. The mean odour emission rates and the ammonia emission rates can be found in Tables 4 and 5 respectively. Both units used temperature controlled variable speed fans in the roof ridge of the houses. The main difference between the two units was the manure handling system and the bird management.

L1 utilised a battery system of cages four tiers high. The manure was removed from the house via a conveyor belt, located beneath each tier, at weekly intervals to an enclosed storage pit. Some drying of the manure occurs while it is on the belt resulting in reduced odour and ammonia emissions from the house. Even greater reductions in odour and ammonia emission can be achieved by blowing air over the manure to achieve faster drying. This also has the additional benefit of fresh cooling air being introduced close to the birds (European IPPC Bureau, 2002). Reductions in ammonia emissions of 58-76% can be achieved depending on frequency of removal. As there is no residue of manure remaining on the belt after cleaning, a lower odour level occurs (European IPPC Bureau, 2002). Directive 1999/74/EC on layer housing

prohibits the installation of caged systems from 2003 and will lead to a total ban on the use of existing designs by 2012. Seedorf and Hartung (1999) reported similar low ammonia concentrations of 2.7 ppm for caged laying hens.

L2 had a deep litter system with the manure stored in the house beneath plastic slats. The manure storage had a notable influence on the odour and ammonia emission rates from the units in comparison to L1. Ammonia emission rates of $0.86 \text{ g d}^{-1} \text{ bird place}^{-1}$ have been reported for this type of housing and manure management system (European IPPC Bureau, 2002). This system is perceived to be more “bird friendly” than the caged systems allowing for the bird to carry out natural behavioral patterns. The reduced stocking density can also result in a dryer litter and therefore lower ammonia concentrations. It is estimated that approximately only 12% of excreta from free range poultry is dropped outdoors (Misselbrook et al., 2000). Any emissions from this manure were outside the experimental boundary and therefore not measured.

Similar emission rates have been reported in studies around Europe. Ogink and Groot Koerkamp (2001) reported ranges of odour emission rates of $0.08 - 0.52 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$ for a similar barn system to L2 and $0.2 - 0.76 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$ for a similar system to L1. A German study (Martinec et al., 1998) indicated that laying hens generated an odour emission rate of approximately $0.5 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$. Sutton et al. (1995) estimated an ammonia emission factor for poultry (layers and broilers) of approximately $0.6 \text{ g day}^{-1} \text{ animal}^{-1}$ from emission factors around Europe.

3.4 Turkey results

The odour samples from the two turkey units were collected on six random days over a three week period toward the end of the crop growth period (Week 16-18). The mean odour emission rates can be found in Table 4. There is no difference between the units other than the ventilation system (i.e. T1 used automatically controlled natural ventilation (ACNV) and T2 used mechanical ventilation). Naturally ventilated houses may have lower odour and ammonia emission rates than forced ventilation housing (European IPPC Bureau, 2002). The type of ventilation system used may also influence the dispersion of odours from the unit and result in a larger impact area.

In growing turkey houses, the birds remain in much longer than in broiler houses; as a result the biochemical process taking place in the litter and ammonia volatilization can be affected (Slobodzian-Ksenicz and Kuczynski, 2002). The BREF document (European IPPC Bureau, 2002) reported a range of ammonia emission rates of 0.52 – 1.86 g d⁻¹ bird⁻¹ using published data from around Europe. Sutton et al. (1995) estimated an ammonia emission factor for turkeys of 1.9 g day⁻¹ bird⁻¹. These results are similar to the range of emission rates reported in this document (Table 5). Phillips et al. (1999) stated that the best methods for reducing ammonia emissions from poultry units based on a ranking exercise were dietary manipulation, exhaust air cleaning and drying of the litter by ventilation systems for both cage and litter poultry systems.

Variations in odour emission rates were observed during the study for all poultry house types. The coefficients of variation (standard deviation as a percentage of the mean) were typically larger for the broiler and turkey units but lower for the layer units (Table 4). This is due to the variations in odour emission rates as the birds grew

over the crop period (Figure 1). Large coefficients of variation are not unusual for sensorial analysis (van Langenhove and De Bruyn, 2001).

The IPC limit of 1 unit for 1 broiler and 2 units for 1 layer and turkey does not relate to the odour emission rates reported. Using the data from this research, it seems that a more likely limit of 1 unit for 1 broiler, 1 unit for 1 layer (depending on the manure handling system) and 8 units for 1 turkey could be used. There is a lack of unanimity in the literature and a scarcity of published data, particularly for turkey odour and ammonia emission rates. The variability in the data highlights the need for individual site assessment.

4. Conclusions

The odour and ammonia emission rates for three similar broiler units, two layer units with different manure handling systems and two turkey units with different ventilation systems were measured.

The broiler units gave a large range of odour and ammonia emission rates depending on the crop day of the batch and the season. As a precautionary principle, the highest odour emission rate per bird should be used when establishing the odour impact area using dispersion models, as this would illustrate the worst case scenario.

A considerable variation between the odour and ammonia emission rates was evident for the two layer units. This is most likely due to the different manure handling systems utilised in the two houses and to some extent may be further influenced by season.

There was no major difference between the two turkey units in regard to odour and ammonia emission rates and concentrations. The type of ventilation system used may influence the dispersion of odours from the unit and result in a larger impact area.

This study indicates odour emission rates to be utilised in dispersion modelling for the different poultry production units. Broilers, layers and turkeys should use 1.22, 0.47 or 1.35 (depending on manure handling system) and $10.5 \text{ ou}_E \text{ s}^{-1} \text{ bird}^{-1}$, respectively. A further paper will report the influence of accurate odour emission rates on determining the odour impact of intensive poultry production units in Ireland using dispersion models.

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Table 1. Poultry unit limits for IPC and IPPC

IPC limit	IPPC limit
100,000 units where	40,000 places for laying
1 broiler place = 1 unit;	hens, broilers, turkeys,
1 layer, turkey or other	ducks and Guinea fowl
fowl place = 2 units	

Table 2. Description of the poultry units

Unit no.	Bird type	Ventilation type	Management system
B1	Broilers	ACNV ¹ – single roof ridge vent, two side vents	Solid floor, 5-10 cm layer of wood shavings.
B2	Broilers	ACNV ¹ – single roof ridge vent, two side vents	Solid floor, 5-10 cm layer of wood shavings.
B3	Broilers	ACNV ¹ – single roof ridge vent, two side vents	Solid floor, 5-10 cm layer of wood shavings.
L1	Laying Hens	Mechanical – negative, 0.6 m diameter roof ridge fans	Belt design battery, belt removal of manure daily egg removal.
L2	Laying Hens	Mechanical – negative, 0.6 m diameter roof ridge fans	Deep litter system, slatted floor, scratching area, daily egg removal
T1	Turkeys	ACNV ¹ – single roof ridge vent, two side vents	Solid floor, 15-20 cm layer of wood shavings.
T2	Turkeys	Mechanical – negative, 0.6 m diameter side wall fans	Solid floor, 15-20 cm layer of wood shavings.

¹ Automatically Controlled Natural Ventilation (ACNV) is a form of natural ventilation by which the airflow through the building is regulated by adjusting the inlets and outlet vents to maintain a preset internal temperature

A = Broiler diet 27% (starter) – 14% (finisher) crude protein; B = Layer diet 17.5 % crude protein; C = Turkey diet 28% (starter) -18% (finisher) crude protein

Table 3. Overview of measurement plan

Parameter (units)	Measurement method	Sample location	Monitoring timescale
Odour (ou _E m ⁻³)	ECOMA T07 olfactometer	Sample collected from exhaust vent	Broilers: last three weeks of crop
			Layers: random three weeks of pro
			Turkeys: last three weeks of crop
Ammonia (ppm)	iTX multi-gas monitor	Sensor at random locations within house (close to ventilation outlet)	Broilers: last three weeks of crop
			Layers: random three weeks of pro
			Turkeys: last three weeks of crop
Ventilation rate (m ³ s ⁻¹)	Determined using	Sensor at random locations	Measured concurrently with odour sampling
	CO ₂ mass balance technique	within house (close to outlet)	

Table 4. Odour emission rates for the different production units

Poultry category	Season	No. of samples	Odour emission rates (ou _E s ⁻¹ bird ⁻¹)				Odour emission rates (ou _E s ⁻¹ kg ⁻¹)			
			Mean	Min	Max	CV (%)	Mean	Min	Max	CV (%)
Broilers										
B1	Winter	73	0.39	0.05	0.93	80.0	0.50	0.18	0.72	40.0
B2	Spring	54	0.33	0.26	1.13	57.2	0.55	0.43	0.71	22.0
B3	Summer	45	0.66	0.45	1.22	49.6	0.66	0.58	0.73	20.2
Layers										
L1	Spring	54	0.47	0.26	0.62	26.6	0.26	0.13	0.45	39.5
L2	Summer	36	1.35	1.06	1.47	14.6	0.67	0.53	0.74	14.6
Turkeys										
T1	Winter	24	5.7	3.5	10.1	50.4	0.53	0.31	0.89	49.5
T2	Winter	24	7.4	5.6	10.5	27.8	0.67	0.57	0.88	19.8

CV: Coefficient of Variation – Standard deviation as a percentage of the mean

Table 5. Ammonia concentrations and emission rates for the different production units

Poultry category	Season	No. of samples	Ammonia concentrations				Ammonia emission rates			
			(ppm)				(g d ⁻¹ bird ⁻¹)			
			Mean	Min	Max	(s.e.)	Mean	Min	Max	(s.e.)
Broilers										
B1	Winter	5385	8.8	7.3	10.1	0.05	0.2	0.1	0.2	0.0009
B2	Spring	2387	9.7	5.7	10.7	0.10	0.3	0.2	0.3	0.003
B3	Summer	1703	9.8	6.3	13.0	0.12	0.5	0.3	0.7	0.006
Layers										
L1	Spring	1435	2.3	0.0	4.3	0.07	0.1	0	0.2	0.003
L2	Summer	1407	7.6	4.6	10.0	0.08	0.5	0.3	0.7	0.006
Turkeys										
T1	Winter	1999	2.3	0.0	4.2	0.06	0.9	0	1.6	0.02
T2	Winter	1379	1.8	0.0	3.2	0.05	0.7	0	1.3	0.02

s.e.: Standard Error of the sample mean

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Figure 1. Mean odour emission rates for three broiler units including interquartile ranges

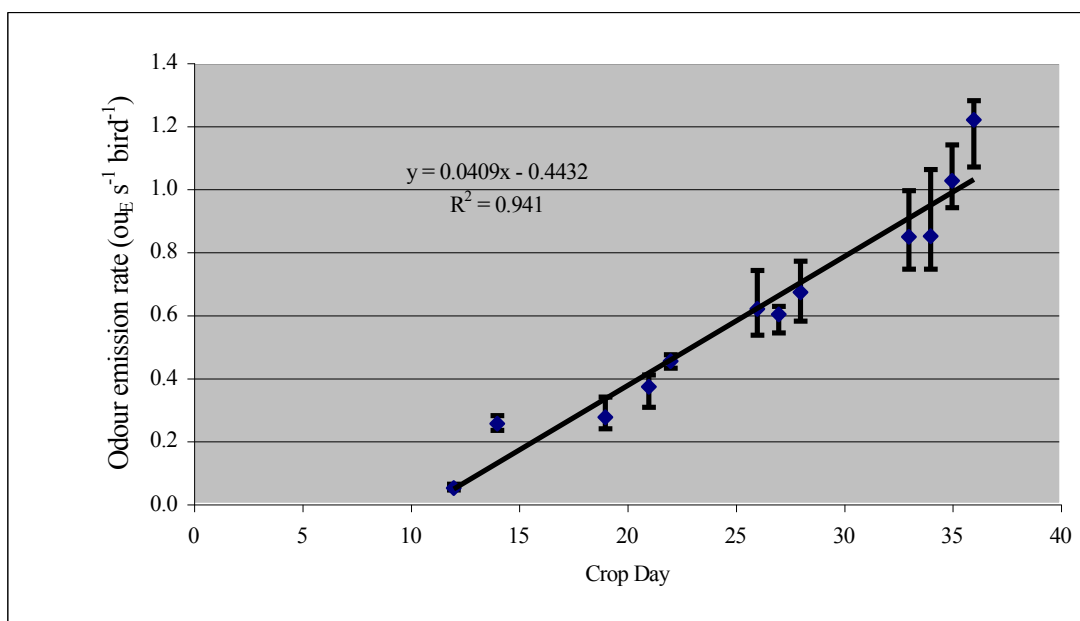


Figure 1. Mean odour emission rates for three broiler units including interquartile ranges