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EXPOSURE ASSESSMENT OF AIRBORNE CONTAMINANTS IN THE INDOOR ENVIRONMENT OF IRISH SWINE FARMS

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Abstract: Agricultural workers have higher rates of long-term sick leave associated with respiratory disease than any other worker groups. There is currently no published data on the extent to which Irish agricultural workers are exposed to occupational respiratory hazards. This investigation focused on Irish swine farm workers in concentrated animal feeding operations and measured their occupational exposure to various respiratory hazards. Swine workers were found to be exposed to high concentrations of inhalable (0.25–7.6 mg/m^3) and respirable (0.01–3.4 mg/m^3) swine dust and airborne endotoxin (<166, 660 EU/m^3). 8 hour Time Weighted Average ammonia and peak carbon dioxide exposures ranged from 0.01–3 ppm and 430–4780 ppm, respectively. Results of this study suggest that Irish swine confinement workers have a potential risk of developing work-associated respiratory disease.

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INTRODUCTION

Agricultural workers are exposed to a number of respiratory hazards, such as particulates, toxic gases and endotoxins, and as a result, tend to have higher rates of asthma and respiratory symptoms than any other occupational group [11]. Data from the Irish National Farm Survey 2003 [20] has shown that 10% of 12,000 Irish farm workers have reported work related illness. One third of these illnesses were respiratory in nature. As the agricultural industry moves from the traditional family setting to concentrated animal feeding operations (CAFOs) there is a need to understand the exposures of workers in such environments. Exposure of swine confinement workers to respiratory hazards has been reported elsewhere in Europe [16, 17, 19] Asia [3] and America [5, 8]. As yet, analogous data has not been reported for Ireland and this omission has hindered the development of policies in the area of occupational health and farm safety. This study assessed worker exposure to airborne contaminants in the indoor environments of Irish swine buildings. Resulting data is compared to recommended health limits, developed by Donham [8] for the prevention of acute respiratory symptoms in swine workers.

MATERIALS AND METHODS

Due to operational constraints, convenience sampling was employed. Teagasc, the Irish Agriculture and Food Development Authority, recommended five swine farms that were geographically spread throughout Ireland and thought to be indicative of the different characteristics of swine farms. Table 1 shows the characteristics of the different swine farms that participated. Swine were housed in

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Table 1. Description of main characteristics of swine farms.

Farm Reference	Number of sows	Number of employees	Age of facilities	Ventilation
1	1,500	12	Old	NV and MV
2	2,200	15	New	MV
3	200	1	Old	NV
4	800	4	Old	NV
5	1,600	9	New	MV

Old = 15–40 years; New = <15 years; NV = natural ventilation; MV = mechanical ventilation with external air

different buildings depending on their growth stage, which were categorised as follows: farrowing unit (pregnant swine, delivered swine and newborn piglets); weaner unit (weaned piglets); fattening unit (swine are fattened before they are sent for slaughter); and dry sow (pre-pregnant and pregnant sows). Swine workers were divided into similar exposure groups (SEGs), which reflected the farm unit in which they worked. The SEGs used were as follows: farrowing unit worker, weaner unit worker, fattening unit worker, dry sow unit worker, and general farm worker. The first four SEGs spent a large portion of their working day in the individual units, while the general farm workers spent their day working throughout all of the swine confinement units. Workers spent on average 5–7 hours per day inside the swine units. 41 workers were monitored during this study. Sampling was carried out on days convenient to the researchers and facilities. This study was conducted during the spring and summer months of 2006, and aimed at measuring the worker exposure for at least 6 hours of the 8-hour working shift. Sampling was suspended during worker breaks (typically 1 hour per shift) and resumed again when operators recommenced their duties.

Participating farm workers were sampled for inhalable and respirable particulates, NH_3 and CO_2. A ToxiPro electrochemical sensor was used to continuously monitor the NH_3 exposure concentrations of the swine confinement workers. The reading values were presented as the average 8-hour time-weighted-average NH_3 concentration (TWA: ppm). CO_2 concentrations were measured using an Anagas CD 98 infrared analyser. The CO_2 analyser employed in this study was only capable of recording the peak CO_2 concentrations (ppm) during the measurement period. For determination of the inhalable and respirable particulate exposure concentrations, personal samples were collected on 25 mm glass fibre filter and polyurethane foam (PUF) mounted in an IOM sampling head. Particulate samples were analysed gravimetrically. After a review of published literature [3] it was decided to measure the potential for endotoxin exposures of weaner and fattening units and general farm workers only, as these workers were found to be exposed to the highest levels of airborne endotoxin. Inhalable endotoxin samples were collected and analysed separately from the particulate samples. Procedures detailed elsewhere [2, 9, 21] were employed for the collection of endotoxin samples. Analyses were carried out at Microchem Laboratories (Irish National Accreditation Board (INAB) accredited) using the Limulus Amebocyte Lysate (LAL) Endosafe Assay (USA). The results were generated as cut-off or break points of endotoxin units, EU/ml and were expressed as EU/m^3 air sampled. Kinetic analysis of emdotoxin levels was not technically feasible for this study.

SPSS package (v. 14.0 for Windows) was used for statistical analysis of worker exposure data. In order to determine differences in exposure between SEGs, data was analysed using a combination of descriptive and inferential statistics. Overall differences in the worker groups' exposures were examined using non-parametric methods.

RESULTS AND DISCUSSIONS

Exposure data for swine confinement worker groups (SEGs) to CO_2, NH_3, inhalable and respirable particulates are presented in Table 2. Peak CO_2 exposures ranged from 430–4780 ppm, and 8 hour TWA NH_3 exposures ranged

Table 2. CO_2 peak exposures, NH_3 8 hour TWA exposures (ppm), Inhalable and Respirable Particulate Exposures (mg/m^3) of the Swine Unit Workers.

SEG Measured	Weaner (ppm)	Fattening (ppm)	Farrowing (ppm)	Dry sow (ppm)	General farm (ppm)
CO_2					
Median ± SD (mg/m^3)	1600 ± 955	1590 ± 991	1554 ± 243	2200 ± 511	4700 ± 113
Range (mg/m^3)	430–2970	1190–3480	1151–1690	1390–2680	4620–4780
N	5	5	4	7	2
NH_3					
Median ± SD (mg/m^3)	0.15 ± 0.44	1.0 ± 0.84	0.55 ± 0.71	1.5 ± 1.07	0.11 ± 0.87
Range (mg/m^3)	0.03–1.0	0.09–2.9	0.09–2.0	0.02–3.0	0.01–2.0
N	8	14	6	6	5
Inhalable					
Median ± SD (mg/m^3)	4.69 ± 2.3	2.31 ± 1.16	1.49 ± 1.51	1.1 ± 0.79	2.99 ± 1.49
Range (mg/m^3)	0.25–7.6	1.9–5.0	0.29–4.4	0.25–3.5	1.1–5.6
N	12	6	10	11	8
Respirable					
Median ± SD (mg/m^3)	0.19 ± 0.19	0.17 ± 0.09	0.09 ± 0.95	0.06 ± 0.11	0.19± 0.24
Range (mg/m^3)	0.03–0.63	0.01–0.3	0.01–3.4	0.01–0.31	0.09–0.63
N	12	6	12	11	7

from 0.01–1.47 ppm. There were no statistically significant differences between the CO_2 and NH_3 exposures experienced by the various workers in the swine confinement buildings. The highest median CO_2 peak value of 4,700 ppm was experienced by the general farm worker group. Whilst 8-hour occupational exposure limit value (OELV) for CO_2 in Ireland is established at 5,000 ppm [10], concentrations in excess of 1,550 ppm are reported in this study. CO_2 concentrations of this magnitude are considered to reflect poor air quality in the swine confinement buildings, which may result in greater potential risk for the development of respiratory disease for the swine workers [8]. The highest median 8 hour TWA NH_3 exposures were experienced by the dry sow and the fattening worker groups (1.5 and 1 ppm, respectively); these are less than the recommended health limit for swine confinement workers exposure to ammonia of 7 ppm [8].

Medians of total inhalable particulate exposures for the worker groups were between 1.11 and 4.69 mg/m^3, with individual values ranging from 0.25–7.6 mg/m^3. Kruskall-Wallis test indicated a significant difference in the median inhalable dust exposures across the worker groups, x^2 (4, n=47)=14.43, p=0.006. Mann-Whitney U tests revealed significant differences in the inhalable particulate exposures between the weaner unit worker and the farrowing (z=-2.308, p=0.021) and dry sow (z=-3.016, p=0.003) worker groups. Furthermore there were significant differences between the dry sow worker and the fattening (z=-2.111, p=0.035) and general farm worker group (z=-2.560, p=0.10). Both the weaner and general farm worker groups (4.69 and 2.99 mg/m^3) were exposed to levels in excess of the recommended threshold limit value of 2.4 mg/m^3 [8]. Respirable particulate exposures were all less than the recommended threshold limit of 0.23 mg/m^3. Reported exposures are comparable to those currently published in the literature, which ranged from 1.32–8.8 mg/m^3 and 0.13–2.5 mg/m^3 for inhalable and respirable particulates, respectively [1, 5, 6, 13, 14, 15, 17, 19]. Much lower average exposure concentrations of 0.24 and 0.14 mg/m^3 of inhalable and respirable particulates respectively have been reported for workers in open style swine houses [3].

The nature of the LAL end-point assay for endotoxin employed in this study facilitated the establishment of a breakpoint endotoxin level of less-than or equal-to, or greater-than or equal-to points up to 166,660 EU/m^3 air. Results indicate that the weaner, fattening and general farm workers were exposed to endotoxin concentrations at concentrations up to 166,660 EU/m^3 air. While the end-point assay results are not directly comparable to other published studies, they are useful for providing quantitative information on the upper level of exposure. Previous studies have reported exposure concentrations of 34,800 EU/m^3, 66,000 EU/m^3, and 49,230 EU/m^3 in the air of dairy farms, cotton mill industry, and swine farms respectively [4, 12, 19]. There are numerous recommended endotoxin exposure limits, ranging from 90–800 EU/m^3 [2, 7, 18]. However accepting the higher recommended exposure limit of 800 EU/m^3, results from this study strongly suggest that exposure to endotoxin among Irish Swine Farm workers is some 200-fold greater than recommended.

CONCLUSIONS

Data presented in this study demonstrates that Irish swine workers are frequently exposed to high levels of CO_2, endotoxin and inhalable and respirable swine confinement dust at concentrations above recommended health threshold limits for the prevention of acute respiratory symptoms in swine confinement workers. As the trend continues towards more intensive live stock production facilities, this study provides occupational health and safety policy makers with data for the development of workplace health protection programmes.

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