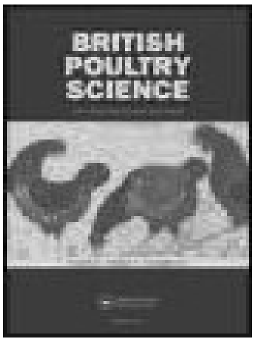

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British Poultry Science

ISSN: 0007-1668 (Print) 1466-1799 (Online) Journal homepage: https://www.tandfonline.com/loi/cbps20

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To cite this article: A. Huneau-Salaün, J. Puterflam, L. Balaine, P. Galliot & S. Le Bouquin (2019): Exposure to inhalable dust of workers shackling birds frequently exceeds occupational exposure level in abattoirs in Western France, British Poultry Science, DOI: 10.1080/00071668.2019.1614529

To link to this article: https://doi.org/10.1080/00071668.2019.1614529

Accepted author version posted online: 08 May 2019.
Published online: 05 Jun 2019.

BRITISH POULTRY SCIENCE
https://doi.org/10.1080/00071668.2019.1614529

Exposure to inhalable dust of workers shackling birds frequently exceeds occupational exposure level in abattoirs in Western France

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ABSTRACT

1. The objectives of this study were to measure the exposure of workers to dust when shackling poultry in abattoirs, and to identify the most effective measures to prevent human exposure to dust. The relationship between respiratory health of workers and their occupational exposure to dust was assessed.
2. Exposure to dust (aerial particles inhaled through the nose and mouth) exceeded the occupational exposure limit (maximum 10 mg/m^3 over 8 h) in 65 out of 109 workers from 27 abattoirs, in the context of high levels of ambient aerial dust in small, closed shackling cubicles. Ceiling air ducts for supply of air reduced worker exposure to dust in these buildings.
3. Two-thirds of the 86 workers interviewed reported work-related respiratory symptoms. The self-reported risk of suffering from coughing tended to be associated with the highest exposure to inhalable dust and respiratory dust (aerial particles penetrating up to alveoli) observed in the study.
4. The present study demonstrates that workers may be exposed to considerable amounts of dust when shackling birds before stunning.

ARTICLE HISTORY
Received 22 November 2018
Accepted 12 March 2019

KEYWORDS
Dust; exposure; occupational health; poultry; slaughter

Introduction

France is the second largest producer of poultry in the European Union, with more than 957 million birds produced in 2015 (FranceAgriMer 2016). About 25,000 people work in poultry slaughterhouses in France. Poultry processing is a highly organised and almost fully automated process, but certain specific tasks still involve human labour and direct contact with animals or their products. Poultry abattoirs, like other meat operators, experience difficulties in human resource management, such as high rates of sick-leave, rapid turn-over of staff, and difficulties in recruiting and retaining workers in the sector (INVS 2009). The multiple occupational risks explain the low attractiveness of work in the meat industries for young people (Caroli et al. 2009). Musculoskeletal disorders are the leading cause of sick leave and occupational disease in personnel working in poultry abattoirs, and incidence was estimated at 33 cases per 1,000 workers in the poultry and meat industry, compared to less than three cases per 1,000 workers in other agricultural sectors in France in 2012. However, there are other risks (Harmse et al. 2016). Several large cohort studies concerning American poultry abattoir workers demonstrated a significant excess risk for non-malignant respiratory diseases and lung cancer in the study population (Netto and Johnson 2003; Johnson et al. 2010). The authors suggested an association between the occurrence of these diseases and respiratory exposure of workers to hazardous biological agents such as viruses. Dust from poultry is also known to contain bacteria, fungi, and associated substances, such as endotoxins, allergens, peptidoglycans, and mycotoxins (Huneau-Salaün et al. 2011).

Among workers in poultry abattoirs, those handling live birds may be more at risk of exposure to organic dust than others. As an example, Williams et al. (2013) observed a higher risk of ornithosis (a respiratory infection due to *Chlamydophila psittaci* and transmitted from birds) for workers in contact with live birds, blood and viscera than for workers in the cutting and packaging areas of poultry abattoirs. Similarly, nasal carriage of gram-negative bacteria was more frequent in people in pre-slaughter areas than in people working in packaging areas or offices (You et al. 2016). In view of these risks, two representative bodies for the poultry sector called on the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) and the French Technical Institute for Poultry Production (ITAVI) to support their efforts in preventing occupational respiratory problems in abattoirs. The main request was to carry out a broad epidemiological study to better assess worker exposure to dust in different types of poultry abattoirs. More specifically, the objectives of the study were to measure the exposure to dust of workers shackling poultry in abattoirs, and to identify the most effective measures to prevent human exposure to dust. Data on the respiratory health of workers were also collected to detect a potential impact of this exposure on workers' health, by comparison with data for the general French population.

Materials and methods

Population

The study was carried out in 23 poultry abattoirs, including 27 slaughter lines in western France, which processed approximately 351 million birds in 2015 (36% of national production). Companies were contacted through the two professional unions of poultry slaughterhouses in France. In this study, the 25 companies were contacted that were located in western France and 23 volunteered to participate in the study. Before the visit for data collection, a questionnaire was sent to the abattoir managers to describe the characteristics of the part of

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the slaughter line dedicated to bird shackling (size, ventilation system, etc.). The information from the questionnaire was used to prepare the measurement campaign and then to analyse the results obtained concerning the exposure of workers to dust.

Process description

The first phases of poultry processing consist of manual or mechanical unloading of birds from transport crates to a conveyor belt. The birds are then shackled on the slaughter line. In most cases, the birds are hung live and conscious upside down by their legs in a shackle, before electrical stunning (Berg and Raj 2015). In an increasing number of slaughterhouses, birds are gas stunned before shackling, and so birds are exposed to an increasing concentration of carbon dioxide, sometimes mixed with inert gases, which leads to bird hypoxia. Gas stunning occurs in a specific chamber or pit, where birds are conveyed on a belt conveyor without human intervention. In this case, birds are unconscious when they are shackled. Shackling is a manual task as no mechanical system has yet been developed. A worker handles between six and 22 birds per minute, depending on the size of the animals and the line speed (from 1,100 to 13,500 birds per hour).

Health data

A physician interviewed the workers face-to-face. Of the 146 persons working regularly in bird handling at the 23 abattoirs, 128 workers gave their prior consent to participate in the study (88%). On the day of the physicians visit to the company, all workers who were present and agreed to participate completed the medical questionnaire. On the day of the dust measurements, all workers at the handling post who agreed to participate were equipped with samplers (dust capture devices). In all, 86 workers completed the medical questionnaire and 106 workers were followed up for dust exposure measures. Regarding the medical interview, the questionnaire requested information on their social characteristics, former professional activities, smoking status, respiratory and skin symptoms, and respiratory diseases. It was adapted from the standardised questionnaire of the European Community Respiratory Health Survey (Burney et al. 1994; http://www.ecrhs.org/quests.htm).

Dust exposure measurement

The individual exposure of workers to inhalable and respirable dust was measured using two individual air samplers (CIP 10, TECORA, France). Inhalable dust is defined as the mass fraction of total airborne particles which are inhaled through the nose and mouth while respirable dust is the fraction which penetrates to the thoracic and alveolar regions (Brown et al. 2013). The workers wore the dust samplers (for inhalable dust and respirable dust) in the breathing zone for about 3 h during the working day. The workers were equipped with a dust sampler during the break (two to 4 h after the beginning of the working day) until the end of the shackling task; the measurement period was limited to the second half of the day work to avoid sampler saturation with dust. The only task carried out during the exposure measurement was shackling birds to the slaughter line. The dust samples were equipped with a pre-weighted filter and the suction pump drew air through it at 10 l/min (NF X 43–262 standard). Blind filters were conditioned in the same way and kept at the laboratory. All exposed filters were dried for 12 h at 37°C and then weighed twice (±0.0001 g, Sartorius Extend ED224S, Sartorius Mechatronics, Goettingen, Germany). The average of the two measurements was retained and a correction taking into account the mass variation of the blind filters was applied. The results were calculated according to air volume and expressed as mg/m^3. In addition to individual exposure measurements, ambient dust concentrations in the handling cubicle or in the shackling area were measured over the work shift period using a dust sampler located 1 m behind the workers shackling birds and at a height of 1.8 m.

Statistical methods

Dust concentrations were presented as means with standard deviations and confidence limits set at 95% ($P < 0.05$). Normality of the data was checked using the Shapiro–Wilk test. Symptoms were reported as frequencies. All the statistical analyses were performed using R software, version 3.4.2. Variables describing shackling cubicle characteristics (Table 1) were visualised using a multiple factor analysis for mixed data. A Hierarchical Ascendant Classification was then carried out to create clusters of lines showing common characteristics (FactoMineR package); variables related to dust concentrations and worker exposures were added as supplementary variables to the analysis. Logistic regressions for repeated measures (within an abattoir) were used to describe the relationship between symptoms and dust exposure (lme4 package). This analysis was carried out on the sub-sample of workers ($n = 62$) for whom both exposure measurements and health data were available. Regression models were adjusted for age.

Table 1. Abattoir characteristics (N = 27 slaughter lines, France, 2016).

Characteristics	Description
Shackling area	Cubicle: 20 Open-space: 7
Shackling area dimensions	Area: 7–125 m^2 (22) Volume: 19–579 m^3 (58) Length: 1.8–24 m (6.2) Shackling height: 1.0–1.6 m (1.4)
Ventilation system	Cubicle fans: 17 Ceiling air ducts: 9 Wall extractor ventilators: 2 Ceiling fans: 5 Natural ventilation: 3
Lighting	Blue light: 17 Dim light: 6 Day light: 2 Artificial light: 2
Temperature regulation	Heating: 6 Air conditioning: 2
Species	Broiler, hen: 19 Turkey: 6 Duck: 2 Quail and pigeon: 1
Line speed (bird/h)	Broiler, hen: 1,100–13,500 (6 000) Turkey: 1,300–8,500 (3 000) Duck: 1,600–3,200 Quail and pigeon: 700
Crate unloading	Manual: 9 Automated: 18
Stunning	Electric stunning: 24 Gas stunning: 3
Number of workers shackling poultry	3 to 13 (6)
Work organisation	1 shift, 8h/day: 22 2 shifts, 2x7h or 2x8h/day: 2 3 shifts, 2x7h + 1x6h/day: 5

Results

The general characteristics of the 27 slaughter lines studied are shown in Table 1.

On three slaugther lines, birds were shackled after gas stunning (CO_2). When the birds were shackled before stunning, the lines were equipped with bars to contain animals and limit bird stress; blue lights were often used or the light was dimmed to limit bird excitation. Of the 186 workers observed (not all equipped with dust samplers), 118 were wearing protective respiratory equipment (60%), 75 wore a surgical mask and 43 had disposable respiratory protection equipment (with or without) an inhalation valve, designed for particle filtration. Ambient dust concentrations (31 measurements) and personal exposures to dust (109 measurements) are shown in Table 2.

One measurement of exposure to inhalable dust was invalid due to sampler malfunction. The mass of dust collected by the samplers was not correlated with the sampling duration (Spearman correlation coefficient $\rho = -0.01$, $P = 0.98$). Sixty-five workers (60%) were exposed to a concentration of inhalable dust higher than 10 mg/m^3, which is the Occupational Exposure Limit (OEL) over an 8 h period. The OEL for respiratory dust (5 mg/m^3) was exceeded for three workers (3%). The sampling duration ranged from 90 to 205 min(149 min, SD = 31 min). Ambient dust concentrations correlated with personal exposure to inhalable dust ($\rho = 0.56$, $P < 0.001$), and to a lesser extent with exposure to respiratory dust ($\rho = 0.18$, $P < 0.01$). The classification analysis distinguished three clusters of abattoirs based on shackling cubicle characteristics and working conditions (Table 3).

The average worker exposure to inhalable dust was lower in one abattoir than in the others (P = 0.02). In this abattoir, the shackling area was a large open space without a ventilation system. In contrast, exposure was higher in 19 small shackling cubicles with mechanical ventilation systems, associated with high concentrations of dust in the ambient air. The ambient dust concentrations in the cubicles in class 1 were significantly reduced by ceiling air ducts (2.9 mg/m^3, CI $_{95\%}$ [1.8–4.0] vs. 7.2 mg/m^3, CI $_{95\%}$ [4.1–10.2], P = 0.04) or wall extractors (1.7 mg/m^3, CI $_{95\%}$ [0.4–3.0] vs. 5.9 mg/m^3, CI $_{95\%}$ [3.8–8.1], P < 0.01). In these buildings, birds were shackled before stunning and the shackling line was short, despite the high line speed. The last class was an intermediate class grouping both abattoirs practising gas stunning and shackling of birds after stunning (three slaughterhouses), and abattoirs specialising in turkey and pigeon processing.

All abattoir workers were employees and their general characteristics are shown in Table 4.

All workers bar one were men. The prevalence of respiratory symptoms varied from 1% for chronic cough to 14% for day and/or night phlegm during the winter period, and for shortness of breath during physical exercise (Table 5).

Work-related symptoms were frequently reported. In total, 44 workers cited at least one symptom, sneezing and coughing being the most prevalent. The workers declaring work-related symptoms attributed the symptoms to exposure to cleaning and disinfectant products (30), to handling live animals (25), to exposure to dust (19), to feathers (2), or to odours (2). Thirteen workers reported requiring medical treatment for respiratory disease during their life, mainly bronchitis (6), pulmonary infection (2), and sinusitis (2). Regarding allergic disorders (asthma, allergic rhinitis, eczema), almost all cases of asthma (7/8) were medically confirmed. Table 6 gives the results of the models assessing the relationship between symptoms and exposure. Smoking was a significant risk for suffering from

Table 2. Ambient dust concentrations and exposures to inhalable dust and to respiratory dust (FranceAgriMer 2016).

	n	Mean ± SD	CI $_{95\%}$	Min-Max
Ambient dust (mg/m^3)	31	4.729 ± 4.438	3.167–6.293	0.143–17.561
Inhalable (mg/m^3)	108	18.347 ± 23.419	13.930–22.764	0.647–135.171
Respiratory (mg/m^3)	109	1.150 ± 2.605	0.661–1.639	0.000–23.902

Table 3. Classification of slaughter lines according to shackling cubicle characteristics and working conditions, and relation to ambient dust concentrations and worker exposures to dust (FranceAgriMer 2016). Quantitative variables are shown as mean with 95% Confident Interval.

		class 1	class 2	class 3
Ventilation System	Mechanical	100%		29%
	Natural		100%	71%
Light	Blue	70%		43%
	Artificial			57%
	Dim light	30%	100%	
Bird stunning	Electric stunning	100%	100%	57%
	Gas stunning			43%
Crate unloading	Automated	83%	100%	29%
	Manual	17%		71%
Heating system	Yes	24%	100%	
	No	76%		100%
Shackling area	Cubicle	87%		43%
	Open-space	23%	100%	57%
Ceiling air ducts	Yes	56%		24%
	No	44%	100%	86%
Bird species	*Gallus gallus*	62%	100%	29%
	Turkey, duck or pigeon	38%		71%
Number of workers		5 to 6	12	3 to 7
Line length (m)		5.2 [4.0–6.3]	9.4	10.3 [8.0–12.6]
Shackling cubicle area (m^2)		32 [24–39]	673	161 [107–216]
Line speed (bird/h)		5 451 [4 880–6 022]	13 000	3 733 [2 490–49 976]
Ambient dust (mg/m^3)		5.37 [3.41–7.32]	0.92 [0.39–1.45]	3.91 [1.05–6.76]
Exposure to inhalable dust (mg/m^3)		23.74 [17.55–29.95]	4.78 [3.57–5.99]	8.33 [5.56–10.71]
Exposure to respiratory dust (mg/m^3)		1.33 [0.60–2.05]	0.32 [0.20–0.44]	0.92 [0.74–1.76]
No. of measurements over OEL for inhalable dust		54/71	2/8	9/28
No. of measurements over OEL for respiratory dust		3/72	0/8	0/28

Table 4. Personal characteristics of the workers (n = 86 abattoir workers, FranceAgriMer 2016).

	n (%)
Sex, n (%)	
Women	1 (1)
Men	85 (99)
Age (mean; SD)	43 (10)
Smoking status, n (%)	
Non-smoker	37 (43)
Ex-smoker	11 (13)
Current smoker	37 (43)
Years worked in the current abattoir (mean; SD)	12 (10)
All years worked in an abattoir (mean; SD)	13 (10)
Childhood, n (%)	
On a farm	14 (16)
In a rural environment (not on a farm)	43 (50)
In an urban environment	29 (34)

Table 5. Health characteristics of the workers (n = 86 abattoir workers, FranceAgriMer 2016).

	Total n (%)
Respiratory symptoms	
Morning cough during winter period	8 (9)
Day and/or night cough during winter period	9 (11)
Chronic cough	2 (2)
Morning phlegm during winter period	11 (13)
Day and/or night phlegm during winter period	12 (14)
Chronic phlegm[1]	1 (1)
Wheezing	10 (12)
Shortness of breath at rest	2 (2)
Shortness of breath during physical exercise	12 (14)
Asthma	8 (9)
Medically-diagnosed asthma	7
Attacks during the last 12 years	2
First asthma attack during childhood	7
Allergic rhinitis	18 (21)
Eczema and other atopic dermatitis	14 (16)
Work-related symptoms	
At least one symptom	55 (63)
Sneezing	44 (51)
Cough	39 (45)
Eyes, nose and/or throat irritation	24 (28)
Fever	3 (3)
Shortness of breath	1 (1)
Headache	1 (1)

phlegm (odds ratio 3.6, CI $_{95\%}$ [1.0–13.0], P = 0.05). The risk of suffering from coughing tended to be associated with exposure to inhalable dust higher than 12 mg/m^3 (OR 4.8, CI $_{95\%}$ [0.8–26.0], P = 0.07), or with exposure to respiratory dust higher than 0.7 mg/m^3 (OR 4.6, CI $_{95\%}$ [0.9–25.0], P = 0.07).

Discussion

To the best of the authors' knowledge, this study is the first to explore associations between exposure and health in such a large number of poultry shacklers in Europe. This study shows that exposure to dust concentrations higher than the OEL can occur for workers shackling birds in poultry abattoirs. The observed exposures were higher than those previously measured in hatcheries (Guillam et al. 2017) and in laying hen houses (Guillam et al. 2013). The OEL for inhalable dust is set at 10 mg/m^3, on average, for an 8-h working period in most European countries. Limiting the measurement period to the second part of the working day may have resulted in an overestimation of the exposure over 8 h, should dust accumulate during the day. However, this makes it possible to assess the worst-case exposure scenario and the OEL was exceeded for 60% of the workers followed up in the current study. The exposure associated with significant pulmonary function decrements in poultry workers was 2.4 mg/m^3 for total dust and 0.16 mg/m^3 for respirable dust according to Donham et al. (2000). These exposures are lower than the official limits: OELs are fixed for inert dust that does not have biological activities. Organic dust as from poultry and slaughterhouses may induce specific health effects (May et al. 2012). Therefore, adverse effects caused by occupational exposure to organic dust (containing bacteria, for example) may occur at a level of exposures lower than the European OELs for non-specific dust. The specific OEL for organic dust is 3 mg/m^3 in Denmark and 5 mg/m^3 in Scandinavia. In comparison with those recommendations, our observations give grounds for concern with respect to the health of poultry handlers.

Wearing adequate respiratory protection equipment for shackling poultry is an absolute necessity, and a particle filter should be present on such equipment. However, one-third of the workers did not wear respiratory protection equipment and another 40% of the workers wore only a basic surgical mask, not adapted for the protection against dust. Shackling poultry is an intense physical activity and finding protective equipment enabling workers to breathe freely may, therefore, be a key aspect in increasing the proportion of workers wearing protective respiratory equipment. In addition, collective prevention and corrective

Table 6. Association between symptoms, health-related characteristics and exposure to dust of poultry shackling workers (n = 64 workers, FRANCEAGRIMER 2016).

	Cough		Phlegm		Shortness of breath during physical exercise						Eczema		Work-related symptoms	
	OR[a]	P	OR	P	OR	P	Asthma		Allergic rhinitis		OR	P	OR	P
Smoker														
Yes	1.40	0.64	3.60	0.05	1.47	0.64	0.49	0.43	0.35	0.16	0.26	0.15	0.67	0.60
No	1		1		1		1		1		1		1	
Childhood														
In an urban area	0.44	0.49	0.65	0.70	N.T[b]		1.13	0.92	0.55	0.59	0.09	0.04	1.00	0.99
In a rural area	1.40	0.73	1.76	0.61			1.09	0.94	0.43	0.45	0.16	0.06	0.81	0.84
On a farm	1		1				1		1		1		1	
Family background														
Asthma and/or allergic rhinitis	1.77	0.43	1.41	0.63	1.52	0.62	15.2	0.09	3.81	0.11	1.10	0.90	3.10	0.18
No antecedent			1		1		1		1		1		1	
Exposure to inhalable dust														
≥12 mg/m ^{3}	4.75	0.07	1.61	0.50	0.34	0.22	2.26	0.40	0.59	0.48	0.69	0.67	1.87	0.41
< 12 mg/m ^{3}			1		1		1		1		1		1	
Exposure to respirable dust														
≥ 0.7 mg/m ^{3}	4.66	0.07	0.03	0.17	0.32	0.15	0.45	0.70	0.30	0.13	0.49	0.42	0.31	0.14
< 0.7 mg/m ^{3}			1		1		1		1		1		1	

[a]Odds Ratio (OR) adjusted for age and the abattoir.
[b]Not tested: the model did not converge due to a low frequency of the symptom in the population studied.

measures need to be improved. In this study, personal exposure to dust closely correlated with ambient dust concentrations which varied between abattoirs. The large number of working places studied (27 slaughter lines) constituted an almost exhaustive sample of the slaughterhouses in the study area (25/27). It reflected the wide variety of abattoirs, as no selection criteria were applied for slaughterhouse enrolment. It was observed that workers in small and closed shackling cubicles were frequently exposed to inhalable dust concentrations higher than the OEL. Ceiling air ducts and wall extractors reduced ambient dust concentrations in shackling cubicles. Nevertheless, exposure to inhalable dust remained higher than the OEL for 62% (celling air duct) and 73% (wall extractors) of the workers, despite ventilation equipment.

Reducing dust generation in shackling cubicles may thus be a more effective strategy to decrease worker exposure. Gas stunning is gradually developing in French poultry abattoirs. In this study, only three abattoirs were equipped with gas stunning systems. The ambient dust concentrations and worker exposure to dust were lower in these abattoirs, but the small number of measurements prevented the observation of a significant effect. When gas stunning is applied, birds are shackled unconscious avoiding movements such as wing flapping or head shaking, which are likely to cause the release of particles from bird plumage. In addition, shackling unconscious birds is less demanding than handling struggling birds. Large-scale abattoirs in France are gradually moving to gas stunning and this modernisation may help to limit both exposure to dust and physical risk factors associated to musculoskeletal disorders among workers. It also constitutes a significant improvement in animal welfare (Berg and Raj 2015).

The population of workers recruited in the study was very specific, with a high proportion of men. This feature is certainly due to the physical demands associated with poultry shackling: it was calculated that a worker lifted 2,700 kg per hour on average. Current smokers accounted for 43% of the workers, more than the average in the male population in France (38%, Guignard et al. 2015). Nevertheless, the frequency of smokers reported for male workers in food industries in France was 44% (INVS 2009), as high as in this study. Current smokers exhibited a higher risk of suffering from phlegm and from wheezing in the study, confirming respiratory impairment due to smoking. A study including 23 poultry shacklers in Sweden reported a lower prevalence of respiratory symptoms than in the current study (Hagmar et al. 1990). The Swedish study observed workers before and after a work shift, and respiratory symptoms reported were those experienced on the day of measurement, whereas the questionnaire used in the current study asked for symptoms occurring over a one-year period. Male predominance and smoking habits make it difficult to compare the health status of the poultry shacklers with the general population in France, or with other populations occupationally exposed to live birds. In a study from 2007, 44% of male French workers reported at least one respiratory symptom during the last year (Provost et al. 2015). This is higher than in the current study sample. Similarly, respiratory symptoms observed in a cohort of Latino-American workers in poultry slaughterhouses were less frequent than in the non-exposed population (Mirabelli et al. 2012). The authors attributed the better respiratory health status of poultry workers to a 'healthy worker' effect. The cross-sectional design in the current study made it impossible to address this potential bias. Nevertheless, a relationship was found between exposure to dust and risk of coughing.

This study showed that workers shackling live poultry in slaughterhouses frequently experienced exposures to inhalable dust higher than the OEL. The exposure to dust was dependent on shackling cubicle design in terms of size and ventilation equipment: closed and small shackling cubicles were more at risk, despite the presence of mechanical ventilation systems. Collective preventive measures must be implemented, as there is a legal obligation to ensure that air quality in workplaces does not lead to exposure of workers higher than regulatory limits. Gas stunning limits dust generation during poultry shackling and may be a more effective way to prevent exposure to dust than other mitigation measures, but this system is not yet common in French abattoirs. Due to the cross-sectional design, the study was limited in its ability to measure the impact of exposure to dust on worker respiratory health. Nonetheless, the data identified the most at-risk situations for exposure to dust, and this is useful both for the implementation of a focused cohort study on worker respiratory health, and as a better guide action for the prevention of occupational risks at poultry abattoirs.

Acknowledgments

The authors are grateful to the poultry companies and workers who participated in this study and to Ms Edet. Funding was provided by FranceAgriMer, FIA and CNADEV.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the France AgriMer [14/096].

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