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Feedback on Measured Dust Concentrations Reduces Exposure Levels Among Farmers

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ABSTRACT

Background: The high burden of exposure to organic dust among livestock farmers warrants the establishment of effective preventive and exposure control strategies for these workers. The number of intervention studies exploring the effectiveness of exposure reduction strategies through the use of objective measurements has been limited.
Objective: To examine whether dust exposure can be reduced by providing feedback to the farmers concerning measurements of the exposure to dust in their farm.
Methods: The personal dust levels of farmers in 54 pig and 26 dairy cattle farms were evaluated in two measurement series performed approximately 6 months apart. Detailed information on work tasks and farm characteristics during the measurements were registered. Participating farms were randomized *a priori* to a control (n = 40) and an intervention group (n = 40). Shortly after the first visit, owners of intervention farms only received a letter with information on the measured dust concentrations in the farm together with some general advises on exposure reduction strategies (e.g. use of respirators during certain tasks). Relationships between measured dust concentrations and intervention status were quantified by means of linear mixed effect analysis with farm and worker id as random effects. Season, type of farming, and work tasks were treated as fixed effects. Changes in exposure over time were explored primarily at a farm level in models combined, as well as separate for pig and cattle farmers.
Results: After adjustment for fixed effects, an overall reduction of 23% in personal dust exposures was estimated as a result of the intervention ($P = 0.02$). Exposure reductions attributable to the intervention were similar across pig and cattle farmers, but statistically significant only for pig farmers. Intervention effects among pig farmers did not depend on the individuals' information status; but among cattle farmers a significant 48% reduction in exposure was found only among individuals that reported to

have been informed. No systematic differences in changes over time considering the use of respiratory protection between the intervention and control groups were observed.
Conclusion: The results of the present study suggest reductions between 20 and 30% in personal exposure to inhalable dust to be feasible through simple information provided to the farm owners regarding actual levels of exposure together with instructions on basic measures of prevention. The exact reasons for these effects are unclear, but likely they involve changes in behavior and working practices among intervention farmers.

KEYWORDS: farmers; inhalable dust; intervention; livestock; organic dust; prevention

INTRODUCTION

The livestock stable environment is potentially hazardous for the respiratory health of workers. Fumes, gases and, most importantly, organic dust dominate the barn air, frequently in concentrations several times higher than the Occupational Exposure Limits (OEL) (Donham *et al.*, 2000; Radon *et al.*, 2000; Spaan *et al.*, 2006; Basinas *et al.*, 2012). Measured personal inhalable concentrations average between 0.8 and 10.8 mg m^{-3} for dust exposure and between 300 and 6600 EU m^{-3} for endotoxin exposure, with no clear time trends in exposure patterns observed within the last three decades (Basinas *et al.*, 2015). As a consequence, occurrence of lung function decline, asthma, acute asthma-like symptoms, chronic bronchitis, bronchial hyper-responsiveness and organic dust toxic syndrome (ODTS) is particularly high among livestock farmers and related stable workers (Vogelzang *et al.*, 1998; Omland, 2002; Eduard *et al.*, 2009; Reynolds *et al.*, 2013).

The need for effective preventive and exposure control strategies for these workers is well acknowledged, but efforts have been historically challenging mainly due to the animal thermo-environmental requirements, the structural changes in the industry, and the intermittent nature of the performed work (Reynolds *et al.*, 2013; Basinas *et al.*, 2015). Ideally exposure reduction and control in the workplace should be achieved through hardware and engineering methods due to their longevity. Alternatively systems based on software or administrative control can also be applied (Gardiner, 2008). Amid the lack of resources and legislation and the complexity of the within stable environment it has been argued that prevention in livestock farmers could be based on promotion of use of respiratory protection during specific work tasks and on administrative control methods (Von Essen *et al.*, 2010). Thus far, non-engineering intervention studies among livestock farmers concerning airborne exposures have mainly focused on education to promote respiratory health through an increased and proper use of respirators (Dressel *et al.*, 2007; Jenkins *et al.*, 2007; Dressel *et al.*, 2009; Donham *et al.*, 2011; Kim *et al.*, 2012). The interest on direct exposure reduction through other intervention tools has been limited; justified also by few studies using quantitative measurements of exposure (Reynolds *et al.*, 1996; Choudhry *et al.*, 2012). Design issues such as improper or total absence of randomization, small sample-size, and solely self-reported based assessment are eminent in many of the above studies. Despite limitations, results have been promising suggesting personalized education to increase the rates of respirator use and thereby leading to reduced occurrence of health symptoms such as ODTS (Donham *et al.*, 2011). Though, use of respirators is considered a low-tier exposure control technique, an exceptional resort only for cases where exposure control by other methods is not feasible or until other effective engineering and administrative methods are established (Gardiner, 2005; Heederik *et al.*, 2012).

The aim of the present study was to evaluate a simple and cheap method towards reduction of livestock farmers exposure to organic dust based on feedback reporting of their measured exposure to dust and advises on exposure reduction strategies. An intervention study with a randomized design was applied to a group of 362 workers and owners of 54 pig and 26 dairy cattle farms from the area of Jutland, Denmark including extensive qualitative information, as well as quantitative measurements of dust exposure.

MATERIALS AND METHODS

The present study was performed within the framework of the exposure assessment for a 15th year follow-up on a Danish cohort study established in

1991, with the aim to examine the effect of farming exposures on respiratory diseases and allergy in a population of 1964 young Danish farmers (Elholm *et al.*, 2010). Details concerning the design, sampling strategy, and the applied measurement and analytical methods can be found in an earlier publication (Basinas *et al.*, 2012).

Selection of farms

At follow-up, information on current employment status and occupational characteristics were available for 1239 participants, of which 403 (34%) were identified as full-time farmers—i.e. working for at least 37 h per week in a farm. Thirty-three dairy cattle farmers and 75 pig farmers were selected randomly in the area of Jutland, Denmark (for pig farms after stratification by farm size). Of the farmers selected, 12 (11 pig and 1 cattle) were reluctant to participate in the study, and 16 (11 pig and 5 cattle) were excluded due to illness, migration, change of occupation or lack of contact. The remaining 54 pig farmers and 26 dairy cattle farmers gave consent for participation. In case selected farmers were employed, consent for participation of the farm in the study was also requested by the farm owner.

Measurement strategy

For every farm included, one summer (1 May to 1 October) and one winter (17 November to 3 April) measurement visit during the years 2008–2009 were established. Visits were randomly performed between Monday and Friday to minimize the possibility of systematic selection of performed work tasks. After consent from the participant and/or farm owner (when the two were different), all workers present on the farms at both baseline (i.e. visit 1) and follow-up (i.e. visit 2) were invited to participate in personal dust measurements, and more than 90% agreed and participated.

The inhalable dust measurements were performed as previously described (Basinas *et al.*, 2012). In short, full-shift measurements were applied and personal sampling was performed at a flow rate of 3.5 l min^{-1} using Conical Inhalable Samplers (CIS; JS Holdings, Stevenage, UK) and glass-fiber filters (Whatman international Ltd, Maidstone, UK). The mass of sampled dust was estimated gravimetrically, after a desiccation period of ≥24 h in a room with controlled climatic conditions. Based on field blanks ($n = 210$), the limit of detection (LOD) was estimated at 0.074 mg/filter, and concentrations were expressed per cubic meter of air (m^3).

Data collection

Personal questionnaires

A questionnaire was used to collect information on age, work experience, education, and smoking habits of non-cohort participants. For cohort participant's similar information was available through the interview and questionnaire surveys used in the health examination part of the study.

Activity diaries

Work tasks performed by each farmer during the measurements, as well as for the following 6 days were documented in structured, self-administrated activity diaries in the form of 30-minute interval checklists. Pre-selected tasks and open entries for task registration, as well as use of respirator were included. Specific diaries for pig, cattle, and field work were used.

Walkthrough surveys

To acquire information on farm characteristics and management processes detailed walk-through surveys were performed during both farm visits. Information on general building characteristics (i.e. type, dimensions, construction and renovation years, interiors, ventilation, flooring etc.), as well as production and management characteristics (e.g. applied feeding, bedding and manure handling practices) were registered for every compartment of the farm.

Randomization and intervention process

After selection the farms were randomized into equal sized control and intervention groups with 13 dairy farms and 27 pig farms in each group respectively. For pig farms randomization was performed after stratification by farm-size similar to the selection of farms in the study (Basinas *et al.*, 2012). The SAS v.9.0 SURVEYSELECT procedure was used in all cases.

In the intervention group, all the farm owners, as well as the workers who were cohort participants received an information letter shortly after the first visit. This contained the measured dust concentrations alongside the tasks performed for each worker on the farm. To allow workers to evaluate their level of exposure, a reference to the established Occupational Exposure Limit for total dust in Denmark (i.e. 3 mg m^{-3}) was also provided along with an approximation to the equivalent amount of inhalable dust (i.e. ~4.5 mg m^{-3}). In case of high levels of exposure, the letter motivated the workers to seek out a reduction of the dust exposure. General advices towards exposure control were provided based on results from previous exposure assessment studies (Attwood *et al.*, 1987; Olenchock *et al.*, 1990; Pearson and Sharples, 1995; Preller *et al.*, 1995; Takai *et al.*, 1996; Takai and Pedersen, 2000). Advices included:

- Avoidance of dust production through administrative methods—i.e. by rinsing or vacuuming instead of sweeping, use of enclosed feed systems, chopping straw in the fields rather than in barns, adding fat to the diet and by regularly removing settled dust from floors, shelves, walls, and ceilings.
- Use of respirators at the most dusty work—i.e. during injection, weighing and movement of pigs, while repairing/maintaining feed barns, silos and ventilation or feeding systems, and while washing with high pressure.

None of the owners or workers on farms in the control group were informed, throughout the course of both summer and winter measurement series; neither about the measured levels of dust exposure in their farms nor about general methods for control and reduction of the exposure.

During the second farm visit, cohort participants and farm owners in the intervention group were asked whether they had received the intervention letter. Due to a postal failure, one of the selected cattle farms did never received it. The received information at an individual level was evaluated by asking all employees in the intervention farms whether they were informed about the existence and the content of the intervention letter. This information was used to categorize individual workers within the intervention group as either being informed or not-informed.

Statistical analysis

Descriptive statistics were used to describe basic attributes of the included farms and workers, and to describe dust measurement results. Because of a right skewed distribution, measured dust concentrations were naturally log-transformed and results are presented as geometric means (GM) with geometric standard deviations (GSD). Farm, worker and sampling characteristics are presented as median (range) values. Chi-square and non-parametric Wilcoxon rank sum tests, and when appropriate Student's *t*-tests, were used for between group comparisons.

Differences in personal inhalable dust concentrations between workers in the intervention group and control group were assessed in linear mixed effect regression analysis (PROC MIXED; SAS version 9.3). A hierarchical model structure was applied with farm and worker (within farm) identity used as random effects. The intervention status was included as a fixed effect. Because our intervention approach allowed changes in processes and exposure levels to occur both at farm and worker level, a tiered analytical strategy was applied. At first intervention effects were examined on farm level, according to random allocation and without accounting whether individuals were informed or not for the intervention letter and its content (i.e. intention-to-treat analysis) (Hollis and Campbell, 1999). Then models on worker level were elaborated using a variable with three categories: intervention informed, intervention not informed, control. Other fixed effects were season (summer versus winter), and type of production (pig versus cattle farming) and individual tasks performed (as dummy variables). Tasks considered were: moving and loading animals, preparation and handling of feed and seeds, feeding, preparation and spread of bedding, washing of stables and installations, repairing and maintenance, administrative/office work and performance of field work. Results with (Model A) and without (Model B) adjustment for tasks are presented further stratified by type of production. For four workers who were involved both in pig and cattle (mainly beef) production, the type of farming was determined by selection and their main working activities during the first measurement visit.

The robustness of the estimated effects was further examined in analyses that included only workers ($n = 174$) with repeated measurements and by excluding measurements ($n = 8$) by workers involved in mixed production activities, as well as from intervention-naïve workers due to postal failure ($n = 7$).

Variance components were estimated using a restricted maximum likelihood estimation (REML) method with a variance compound covariance structure assumed. Statistical significance was set at 5% level. Changes in use of respiratory protection over time were evaluated by comparing the activity diaries from both periods.

RESULTS

A total of 312 farm owners and farm workers (hereafter simply referred to as farmers) participated in the study; 163 worked on intervention farms and 149 on control farms. There was no statistical difference in characteristics across farms, farmers and measurements between the control group and the intervention group (Table 1). Similarly, activity patterns in the intervention and control groups did not systematically differ across pig or cattle farmers, except for field work which was performed more frequently in the control than the intervention group of pig farmers (11 versus 4%; χ^2 test $P = 0.01$). Out of 124 intervention participants measured during the second farm visit, 10 (37%) cattle and 60 (31%) pig farmers were not informed about the intervention letter and its content.

Measured inhalable dust concentrations varied at both baseline and follow-up irrespective of the intervention status and the type of farming involved (Fig. 1). The arithmetic mean (SD) inhalable dust concentration was 4.3 (5.0) mg m^{-3} for control farmers and 3.8 (3.4) mg m^{-3} for intervention farmers. At baseline there were no differences in levels of dust exposure among control and intervention pig farmers; but among cattle farmers, exposure in the control group was significantly higher than in the intervention group (Table 2). After intervention the levels of exposure increased, probably as a result of seasonal changes in task patterns, by 29% in control pig farmers and 13% in intervention pig farmers, and by 3% in the control cattle farmers and 16% in intervention cattle farmers. Restricting the analysis to only repeated measurements yielded similar results for the overall population and pig farmers (Supplementary Table S1 is available at *Annals of Occupational Hygiene* online). Though, among cattle farmers baseline differences in exposure among intervention and control farms somewhat declined, and a non-significant 16% decrease between baseline and follow-up dust concentrations was seen in intervention farmers. There were no correlations at a farm level between the status of intervention and the season (Spearman rank correlation coefficient = −0.003; $P > 0.05$).

Table 3 summarizes the results of the intervention at farm level (intention-to-treat analysis) as estimated from mixed effect linear regression models with and without adjustment for performed tasks during the measurements. The complete model results with estimates for all parameters included are summarized in Supplementary Tables S2 and S3, available at *Annals of Occupational Hygiene* online. After adjusting for season there was an overall significant 21% decrease in dust exposure in the intervention group compared to the control group of farmers (Table 3; Model A). There was no significant interaction between intervention status and type of production ($P > 0.05$) and in stratified analysis effects for the subpopulations of pig and cattle farmers were of similar size, though not statistically significant. Further adjustment for performed tasks strengthened the intervention effects; estimated reductions in personal dust levels attributed to intervention were 31% for cattle farmers and 27% for pig farmers, statistically significant for the latter (Table 3; Model B). Results were similar when we excluded non-repeated measurements (data not shown).

In the mixed models with the intervention status on the worker level and accounting for the individuals' information status (Table 4), results were generally supportive to the ones of the intention-to-treat analysis. Following adjustment for tasks (Table 4; Model B) there was a clear protective effect of the intervention in informed participants both for the overall population and for the specific strata of pig and cattle farmers; effects were somewhat stronger among cattle farmers. Interestingly, a 30% reduction in personal dust levels was evident also among non-informed farmers of intervention pig farms. No intervention effects were observed among non-informed cattle farmers. Complete model results are shown in Supplementary Tables S4 and S5, available at *Annals of Occupational Hygiene* online. Similar results were obtained in analysis with adjustment for tasks restricted to individuals with repeated measurements (not shown).

Sensitivity analysis at both farm and individual level after excluding measurements from workers in mixed production farms and those who remained naïve due to post failure did not changed the results (not shown).

Table 1. Comparison of measurement, farm and worker characteristics across intervention and control farms. Data are presented as median (range) values, unless otherwise stated

	Control farms ($n = 40$)		Intervention farms ($n = 40$)	
	Pig ($n = 27$)	Cattle ($n = 13$)	Pig ($n = 27$)	Cattle ($n = 13$)
Farm characteristics[a]				
Full-time employees per farm	4 (1–9)	3 (1–9)	3 (1–21)	3 (1–7)
Size in hectares	268 (0–850)	175 (95–530)	238 (0–1200)	214 (42–365)
Size in Animal Units (AU)	150 (50–490)	222 (169–697)	181 (21–620)	240 (63–474)
Pigs housed	5105 (1760–18 516)		5954 (1400–20 686)	
Cattle housed		295 (233–890)		305 (82–720)
Worker characteristics				
Total farmers sampled, *n*	108	41	127	36
Intervention information status, *n* (%)				
Informed	0 (0)	0 (0)	67 (52.8)[b]	17 (47.2)[b]
Not informed	108 (100)	41 (100)	60 (47.2)	19 (52.8)
Workers with dust levels above 4.5 mg m^{-3} during first visit, *n* (%)	30 (27.8)	2 (4.9)	30 (23.6)	2 (5.5)
Gender, *n* (%) males	86 (80)	32 (78)	108 (85)	28 (78)
Years working in farming	6 (0–36)	8 (0–46)	7 (0–50)	12 (0–32)
Years working in current farm	2 (0–28)	2 (0–12)	1 (0–23)	1 (0–32)
Age	28.5 (16.3–57.2)	25.3 (16.7–61.3)	29.6 (16.5–65.3)	30.5 (17–53.1)
Current smokers, *n* (%)	38 (35)	6 (15)	42 (33)	8 (23)
Nationality, *n* (%)				
Danish	82 (76.0)	31 (75.6)	82 (64.6)	29 (80.5)
Other	26 (24.0)	10 (24.4)	45 (35.4)	7 (19.5)
Using respiratory protection, *n* (%)	22 (20.4)	2 (4.9)	19 (15.0)	3 (8.3)

Table 1. *Continued*

	Control farms ($n = 40$)		Intervention farms ($n = 40$)	
	Pig ($n = 27$)	Cattle ($n = 13$)	Pig ($n = 27$)	Cattle ($n = 13$)
Measurement characteristics				
Total measurements performed, *n*	169	66	193	58
Months between repeated measurements	6.8 (3–9.8)	6.2 (2.6–8.6)	6.6 (3–11.1)	6.8 (4.2–8.7)
Minutes of sampling time	387 (65–522)	278.5 (51–719)	383 (107–552)	294 (61–459)
Performed task, *n* (%)				
Moving and loading animals	86 (50.9)	15 (22.7)	115 (59.6)	16 (27.6)
Preparation and handling of feed and seeds	51 (30.2)	32 (48.5)	56 (29.0)	30 (51.7)
Feeding	95 (56.2)	43 (65.2)	118 (61.1)	37 (63.8)
Preparation and spread of bedding	56 (33.1)	36 (54.6)	57 (29.5)	33 (56.9)
Washing of stables and installations	29 (17.2)	18 (27.3)	46 (23.8)	11 (19.0)
Repairing and maintenance	36 (21.3)	8 (12.1)	48 (24.9)	5 (8.6)
Administrative/office work	21 (12.4)	4 (6.1)	25 (13.0)	6 (10.3)
Field work	19 (11.2)*	7 (10.6)	8 (4.2)	7 (12.1)

[a]Baseline values (first visit) are summarized.
[b]Pertains only to workers that participated in the second (follow-up) measurement series.
*Significantly different ($P < 0.05$) from corresponding intervention group.

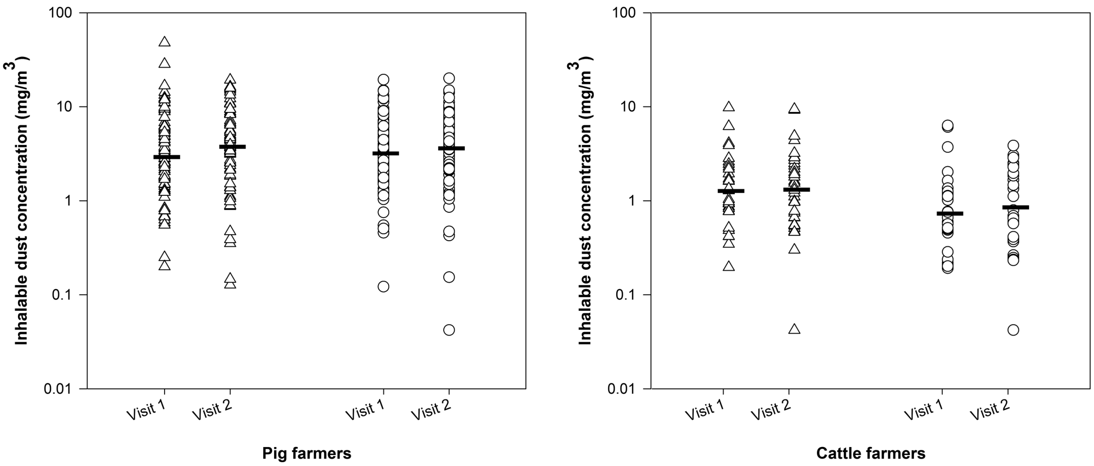

Figure 1 Results of personal dust measurements prior (visit 1) and post (visit 2) to intervention across pig (left) and dairy cattle (right) farmers belonging to the control (triangle) and intervention (circle) groups of farms. Horizontal lines are Geometric Mean levels.

Table 2. Comparison of personal inhalable dust levels (mg m^{-3}) across the intervention and control groups of farms in the study. Overall, and results per type of farming and visit are presented

	Control farms (f = 40)				Intervention farms(f = 40)			
	k	n	GM (GSD)	Min–Max	k	n	GM (GSD)	Min–Max
Overall population								
Visit 1	118	118	2.34 (2.86)	0.20–47.82	127	127	2.23 (2.91)	0.12–19.38
Visit 2	117	117	2.74 (3.06)	<LOD–19.27	124	124	2.63 (3.05)	<LOD–20.02
Pig farmers								
Visit 1	87	87	2.91 (2.79)	0.20–47.82	96	96	3.19 (2.31)	0.12–19.39
Visit 2	82	82	3.75 (2.72)	0.13–19.27	97	97	3.61 (2.47)	<LOD–20.02
Cattle farmers								
Visit 1	31	31	1.27 (2.39)[a]	0.20–9.80	31	31	0.73 (2.56)	0.19–6.31
Visit 2	35	35	1.31 (2.82)	<LOD–9.43	27	27	0.85 (2.91)	<LOD–3.86

f, number of farms included; GM, geometrical mean; GSD, geometrical standard deviation; *k*, number of workers sampled; *n*, number of measurements.
[a]Significantly different from the intervention group.

The information from the seasonal weekly activity diaries was used to assess whether patterns in use of respiratory protection differed between the comparison groups, as well as over time (Table 1). Use of respirators was comparable between intervention and control pig and cattle farmers at both baseline (12.6% versus 11.4 % and 3.2% versus 9.7% for pig and cattle farmers, respectively) and follow-up (11.6% versus 19.4 % and 3.7% versus 5.7% for pig and cattle farmers, respectively). There were no statistically significant differences in use of respirators over time either (χ^2 test $P > 0.1$ in all strata).

DISCUSSION

This study summarizes the effects of a simple administrative intervention to decrease dust exposure among livestock farmers. Its results suggest that reductions between 20 and 30% in personal exposure to inhalable

Table 3. Relative effect of the intervention on the personal dust exposure concentrations as estimated in mixed effect linear models with the intervention status at farm level (intention-to-treat analysis). Results are based on 486 measurements from 312 workers employed in 80 Danish farms

Intervention status	Model A[a]		Model B[b]	
	exp(b)	95% CI	exp(b)	95% CI
Overall population				
Intervention	0.79	0.63–1.00	0.77	0.61–0.96
Control	Ref		Ref	
Pig farmers				
Intervention	0.79	0.62–1.03	0.73	0.58–0.93
Control	Ref		Ref	
Cattle farmers				
Intervention	0.78	0.51–1.20	0.69	0.43–1.11
Control	Ref		Ref	

CI, confidence interval.
[a]Adjusted for season (summer versus winter).
[b]Adjusted for season (summer versus winter) and work tasks performed.

dust may be feasible by feeding back information to the farmers regarding their measured exposure levels alongside instructions focusing on basic measures of dust control.

Overall, the intervention effects among pig and cattle farmers were similar. Interestingly though, when the individuals information status was taken into account a significant 30% reduction in personal dust levels was evident also among non-informed farmers of intervention pig farms. Since the information status of these farmers was identical to the one of controls, there is no reason to believe that these findings result from an observer bias—i.e. systematic differences in temporal changes of behavior because of participation in the study or because of the presence of the investigators. Thus, it is most likely that for these workers process and behavioral alternations have occurred at farm level. The impact of behavior and work style on exposure is well acknowledged in the literature (Lazovich *et al.*, 2002; Elms *et al.*, 2005; Baatjies *et al.*, 2014). Except for the use of respirators, for which no differences occurred between intervention and control pig farms, behavior and work style were not incorporated in our study.

On cattle farms though, intervention effects were observed only among farmers informed about the intervention letter and its content (Table 4). Most of these (77%) were farm owners and managers, who were older (median age: 33 versus 23.6 years) and more experienced (median years in farming: 16.3 versus 2) than those who stayed uninformed. Similar, but less pronounced, differences in age (median age: 31.8 versus 25.9 years) and working experience (median years in farming: 13 versus 3.5) were observed also in the intervention pig farms. It has previously been shown among rubber manufacturing workers that seniority (i.e. experience) may lead to steeper reductions in exposure to inhalable particles (Vermeulen *et al.*, 2000). These findings could therefore relate to an increased efficiency in exposure reduction measures by more experienced workers, possibly as a result of their better familiarity with the production process or by shifting known dustier tasks to less experienced workers. Alternatively, they could, at least partly, be explained by differences in number of workers per company, work structures and team meetings between pig and cattle farms. An examination of the tasks for these workers did not reveal systematic differences over time in the total number of high versus

Table 4. Relative effect of the intervention on personal dust exposure concentrations as estimated in mixed effect linear models with the intervention and information status at individual level. Results are based on 486 measurements from 312 workers employed in 80 Danish farms

Intervention status	Model A[a]		Model B[b]	
	exp(b)	95% CI	exp(b)	95% CI
Overall population				
Intervention informed	0.76	0.59–0.99	0.75	0.58–0.97
Intervention not informed	0.87	0.61–1.24	0.81	0.58–1.13
Control	Ref		Ref	
Pig farmers				
Intervention informed	0.79	0.59–1.07	0.75	0.58–0.97
Intervention not informed	0.79	0.54–1.18	0.70	0.50–1.00
Control	Ref		Ref	
Cattle farmers				
Intervention informed	0.59	0.36–0.97	0.52	0.30–0.88
Intervention not informed	1.39	0.73–2.66	1.21	0.62–2.35
Control	Ref		Ref	

CI, confidence interval.
[a]Adjusted for season (summer versus winter).
[b]Adjusted for season (summer versus winter) and performed work tasks.

low exposed tasks performed at baseline and follow-up between informed and non-informed farmers (not shown).

Direct comparisons of our results with other studies is not possible as, to our knowledge, similar data among farmers have not been published before. In an earlier US study, 207 randomly selected pig farmers were allocated into intervention and control groups on the basis of the geographical location of their farms (Donham *et al.*, 1990). Workers in intervention farms received education and training in prevention through self-study modules and group lectures, and industrial hygienists provided consultation. Personal repeated measurements were collected with an interval of 5 years, and a 20% reduction in levels of total dust exposure between baseline (mean = 4.55 mg m^{-3}) and follow-up (mean = 3.55 mg m^{-3}) was observed (Reynolds *et al.*, 1996). The authors suggested differences to be a result of the appliance of control measures in intervention farms. However, formal statistical comparisons of over time changes in exposure between intervention and control workers were not included, and effects of task differences across time-points were not taken into account. Work tasks have been shown to have a considerable effect on the daily personal level of farmers' exposure to organic dust (Basinas *et al.*, 2013; Basinas *et al.*, 2014).

Another intervention study on 10 intervention and 10 control workers of one dairy farm, which included quantitative measurements of exposure, tested the effectiveness of increased frequency of parlor washing on reducing dust and endotoxin exposure among the workers (Choudhry *et al.*, 2012). Respirable and inhalable dust and endotoxin measurements were performed at single shifts. The authors reported 20 to 50% decreased levels of exposure in intervention workers compared to controls, statistically significant only for respirable dust. The Choudry study demonstrated the usefulness of non-engineering control measures in reducing dust and endotoxin exposure of farmers. However, the study was small and in addition repeated measurements of the same workers were not performed, and therefore effects of systematic between- and within-workers variations in exposure remained unaccounted for.

Intervention studies in other industries involving objective measurements of dust exposure are also few. In Lazovich *et al.* (2002) 48 wood-processing factories were provided with written feedback on measurement results and recommendations for reducing exposure. After randomization the effectiveness of technical assistance and worker training was examined. A 10.4% reduction in dust levels was observed in intervention compared to control factories. The authors attributed the small intervention effects to a short observational period, a non-intensive intervention design, potential dilution due to the fact that feedback was also given to control factories, and to contamination among the control factories through encounters with owners and workers from intervention factories.

More severe effects of contamination among the controls were reported in a recent intervention study among South African bakers (Baatjies *et al.*, 2014), probably as a result of all the included bakeries belonging to a single chain of supermarket stores. Knowledge exchange and movement of managers or personnel (e.g. due to job rotation) are likely to be more frequent within than between companies. Our study included only independent farms, and we observed no movement of personnel between farms. Yet, we were unable to assess the likelihood of sharing of information between control and intervention farmers from personal and/or private encounters. The clear intervention effects in our study argue against a considerable presence of such contamination. There is a need for future studies with designs that aim to minimize the risk of such contamination and that includes better assessment of changes in behavior and work practices and the decisions that brought such changes about. In addition, when it comes to dynamic working environments such as construction and farming, the effects of interventions may be confounded by changes over time in potential or known exposure affecting factors like the work location or the season. It is therefore important for future studies to adhere into designs that allow controlling for such changes, which can be achieved through a detailed full-shift exposure assessment gaining insight in the underlying determinants of the exposure (van Deurssen *et al.*, 2015).

Besides season, the level of farmers' personal exposure to dust depends on the actual work tasks performed and is strongly influenced by the characteristics of the stables and the feeding practices applied (Basinas *et al.*, 2013; Basinas *et al.*, 2014; O'Shaughnessy *et al.*, 2010; Samadi *et al.*, 2012). In addition to the control for seasonal variations we were able to control for differences in the performed tasks by the farmers. Yet, we were unable to account for variations in exposure between visits due to differences in the presence of the farmers in different stables of various types and housing characteristics. Given the limited time between the two surveys (on average half a year) we do not have any reason to believe that major production process changes have influenced our results. Further studies are warranted that take into account also behavioral factors like work style.

When measurements are repeated on the same workers as in our study, relatively high or low observations may likely be followed by less extreme ones that are nearer to the subjects true mean—the so-called 'regression to the mean (RTM)' phenomenon. Consequently, changes in natural variation may look like real effects (Barnett *et al.*, 2005). We anticipated that RTM effects would be reduced due to their expected equal distribution across the comparison groups obtained by randomization (Barnett *et al.*, 2005). The lower dust levels of control cattle farmers compared to intervention cattle farmers at baseline and follow-up challenges this interpretation. Considering the homogeneity of the comparison groups in relation to their basic characteristics, the differences in dust levels between groups are likely to be due to chance. Such differences were not present, neither among pig farmers nor among the overall study population. Therefore, we do not expect these differences to have a strong impact on the overall conclusions of the study.

The validity of the applied sampling strategy and of the analytical methods of our study has been thoroughly discussed in several previous publications (Basinas *et al.*, 2012; Basinas *et al.*, 2013; Basinas *et al.*, 2014). Briefly, because of a random selection, farms included in our study can generally be considered as a representative sample of Danish farms. In addition, the overall dust concentrations that we measured among pig (GM = 3.4 mg m^{-3}) and cattle (GM = 1.0 mg m^{-3}) farmers are comparable with those previously reported among pig (range of averages:

2.6–5.0 mg m^{-3}) and cattle (range of GMs = 0.89–1.4 mg m^{-3}) farmers in Northern Europe (Radon *et al.*, 2002; Spaan *et al.*, 2006; Samadi *et al.*, 2012). Methodological differences between these studies and our study are minimal and it is suggested that analytical errors play little role in the variation of measured concentrations in farming populations (Basinas *et al.*, 2015). Strengths of our study are the large sample of farms and farmers included, and the rigorous exposure assessment protocol that allowed us to collect information on several potential exposure affecting factors. Limitations are the lack of extensive data on changes in worker style and behavior during task performance and our inability to inform all workers in intervention farms about the intervention letter and its content. It is likely that the efficiency of our intervention would have increased if the information feedback had been tailored towards specific changes in work style and behavior during task performance and had been supported by personal training sessions. Furthermore, follow-up measurements were obtained only once after a period of approximately 6 months following the intervention implementation in our study. Thereby the long term sustainability of the demonstrated reductions in exposure could not be assessed.

CONCLUSIONS

In conclusion, we evaluated a simple and cheap method to reduce the exposure of livestock farmers to organic dust. Its results suggest that reductions between 20 and 30% in personal exposure to inhalable dust may be feasible by simple feedback on measured levels of exposure together with instructions towards basic measures of prevention. Most likely these effects resulted from changes on working style and behavior during task performance by intervention farmers. Further studies incorporating information on personal behavior and work style will be needed to validate our findings.

SUPPLEMENTARY DATA

Supplementary data can be found at http://annhyg.oxfordjournals.org/.

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