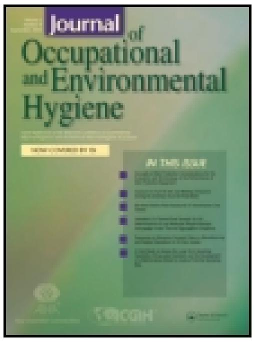

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Case Study
Evaluation of Parlor Cleaning as an Intervention for Decreased Occupational Exposure to Dust and Endotoxin Among Dairy Parlor Workers—A Pilot Study

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INTRODUCTION

A greater prevalence of respiratory symptoms has been observed among workers involved in animal production compared to other farmers and rural residents.(1) In addition, respiratory diseases such as byssinosis,(2) asthma,(3) allergic alveolitis,(4) chronic bronchitis,(5) and the organic dust toxic syndrome (ODTS)(6) have been reported among workers in the animal feed industry, slaughterhouses, compost facilities, and other agriculture-related industries.(7) Respiratory hazards such as organic dust, microorganisms, fungi, molds, and endotoxin are common in the dairy industry.(8) Exposure to organic dust and endotoxin may lead to pulmonary inflammation among dairy parlor workers.(9–11)

Organic dusts are associated with intensive livestock operations, such as dairy, swine, and poultry production; however differences in the components of these organic dusts have been reported.(12,13) A substantial amount of work has evaluated the effects of organic dust exposure among swine workers, whereas less is known about these exposures among dairy parlor workers.(13–16)

Sources of organic dust on dairy farms include feed/hay grinding and animal sources, such as hair and feces.(17) Little information is available on the impact of these exposures among workers in the dairy industry. However, a few studies have demonstrated an association of dust and endotoxin exposure with markers of lung inflammation among dairy parlor workers.(9,12,18)

The primary task of dairy parlor workers is to milk the cows. Cows are moved through the parlor building using workers to guide the animals as well as mechanical gating systems. Cows enter the parlor on an elevated platform for milking.

Cows are typically milked three times a day over a series of three 8-hr shifts.(19) The walkways and other surfaces that come into contact with the animals become soiled with animal waste. Workers use an automated cleaning system to remove animal waste from the parlor surfaces. Therefore, increasing the frequency in which these walkways and other surfaces are cleaned may reduce the concentration of aerosolized dust and endotoxin in the milking parlor.

Parlor workers spend their work shift in proximity to cows and animal waste, which may be sources of inhalation exposure to organic dust and endotoxin. Therefore, these workers may be more exposed to inflammatory agents, as organic dust and endotoxin, compared to other workers on the dairy farm.

The objective of our study was to assess occupational exposure to dust and endotoxin among dairy parlor workers. This study also evaluated the effectiveness of increasing the frequency of cleaning the dairy parlor surfaces on dust and endotoxin inhalation exposure among parlor workers.

Frequent cleaning of parlor surfaces may decrease inhalation exposure to agents such as organic dust and endotoxin. Results of this study may have a significant impact on understanding inhalation exposures among parlor workers and provide information about the effectiveness of cleaning practices on decreasing inhalation exposure to inflammatory agents in the dairy parlor. If proved successful, the proposed intervention could be easily implemented on other dairy farms, as the equipment used is common among farms in the industry.

MATERIALS AND METHODS

Study Population and Conditions

In this study, inhalation exposures to dust and endotoxin were measured among 10 dairy parlor workers during one 8-hr work shift under normal working conditions. Typically, the milking parlor and walkways were cleaned four times per work shift. Dust and endotoxin concentrations on 10 additional dairy parlor workers were also measured while implementing an increased cleaning schedule or "intervention" condition ($n = 20$). Under the intervention condition, the milking parlor was cleaned eight times during an entire 8-hr work shift. The cleaning process was standardized as animal waste and soil were cleaned off the cow walkways and other surfaces with the help of an automated system that used recycled water from the animal waste lagoon. A total of 20 workers participated in the study. Institutional Review Board approval was obtained before implementation of the study procedures. All workers were paid $40 for their participation.

Sampling Equipment and Procedures

Concentrations of dust and endotoxin were measured in the breathing zone of the dairy parlor workers (Figure 1). Respirable dust was sampled using the SKC Aluminum Cyclone (SKC Inc., Eighty Four, Pa.). A 5-μm pore polyvinyl chloride membrane (PVC) filter was used to collect a respirable fraction of the dust. A cyclone was attached to each cassette and connected to a personal sampling pump using flexible tubing. Respirable dust samples were collected at a flow rate of 2.5 L/min, with a 50% cut point of 4 μm according to NIOSH Method 0600, Particulates not Otherwise Regulated, Respirable. The Institute of Medicine (IOM) Inhalable Sampler (SKC Inc.) was used to collect inhalable dust using sampling cassettes and 25-mm-diameter PVC filters with a 5 μm pore size and a 50% cut point for 100-μm-sized dust particles (Figure 2). The PVC filters were weighed and placed in the IOM cassette.

Both the cassette and the filter were pre- and post-weighed as a single unit. The personal sampling pump was calibrated to a flow rate of 2 L/min. Airflow was measured before and after the sampling was completed, and average value of the airflow was used for calculation of sampled air volume. After sampling, the cassettes and IOMs were removed and stored for gravimetric analysis. All personal pumps were calibrated using the DryCal DC-Lite primary airflow meter (BIOS International, N.J.) both before and after sample collection.

FIGURE 1. Dairy parlor work environment.

Gravimetric Analysis of Dust

All samples were placed in the desiccating chamber with silica beads for 12 hr to remove excess water before post-weighing. After desiccation, all samples were re-equilibrated to temperature and humidity in the lab. All field blanks ($n = 12$) were handled in the same manner as the samples. The mass of dust collected on filters was determined gravimetrically by post-weighing filters on a Mettler MT5 balance (Mettler-Toledo, Inc., Columbus, Ohio). Dust concentrations were calculated and reported in mg/m^3.

Endotoxin Analysis Using rFC Assay

The rFC endotoxin assay (Cambrex, East Rutherford, N.J.) was used to analyze the level of endotoxin in the inhalable and respirable dust samples. The fluorescence generated by the enzymatic cleavage of a synthetic tripeptide coumarin substrate allows activation of rFC.[20] The endotoxin standards

FIGURE 2. Placement of dust and endotoxin samplers.

were incubated at 37°C for 1 hr and then the fluorescence was measured. The endotoxin standards and collected air samples were extracted in 10-mL pyrogen-free water (Lonza Inc., Walkersville, Md.) containing 0.05% Tween-20 (extraction media).

All samples were loaded into a 96-well plate along with 100 μL of the enzyme mixture, buffer, and fluorogenic substrate. KC4 software (version 3.4; Bio-Tek Instruments, Winooski, Vt.) was used to read sample results in a fluorescence microtiter plate reader (FLx800 TBIE; Bio-Tek) at excitation/emission 340/440 nm. The endotoxin concentrations were calculated according to a standard curve.[21,22]

Statistical Analysis

Study data were analyzed using SPSS version 18 (SPSS Inc., Chicago, Ill.). The Wilcoxon signed-rank test was used to examine the relationship between dust and endotoxin concentrations under both normal and intervention conditions. The level of statistical significance for all analyses was set at an alpha level of 0.05.

RESULTS

A summary of exposure concentrations are detailed in Table I. Mean exposures were reported in the following four categories: (1) respirable dust (mg/m^3), (2) inhalable dust (mg/m^3), (3) respirable endotoxin (EU/m^3), and (4) inhalable endotoxin (EU/m^3) (Table II). Under normal conditions, respirable dust concentrations were 0.25 mg/m^3 and decreased to 0.12 mg/m^3 under intervention conditions (Table I). For respirable endotoxin, the mean concentration decreased from 5.58 to 3.96 EU/m^3 under treatment conditions. Similarly, inhalable dust and endotoxin concentrations also decreased from 3.98 to 2.26 mg/m^3 and from 1108 to 875 EU/m^3, respectively.

Results from the Wilcoxon signed-rank test indicate a statistically significant decrease ($p = .01$) in exposure to respirable dust under intervention conditions (Table I). However, no statistically significant differences ($p > .05$) in exposure were observed for inhalable dust, inhalable endotoxin, and respirable endotoxin when normal conditions were compared to intervention conditions. Statistically significant differences were also observed among the relative humidity levels, inside the dairy parlor, under normal and intervention conditions ($p = .007$).

DISCUSSION

The purpose of this study was to evaluate the effect of increased cleaning of dairy parlor surfaces on reducing the occupational exposure to dust and endotoxin among dairy parlor workers. By using the Wilcoxon signed-rank test, we determined a statistically significant decrease ($p = .01$) in personal exposure to respirable dust after comparing the normal and intervention cleaning conditions. However, for all other categories the null hypotheses were not rejected, although inhalable dust levels did decrease with increased cleaning. Statistically significant differences were also observed between the relative humidity levels inside the dairy parlor under

TABLE I. Dairy Parlor Worker Exposure Concentrations to Dust and Endotoxin

Subject	Treatment	Respirable Dust (mg/m^3)	Respirable Endotoxin (EU/m^3)	Inhalable Dust (mg/m^3)	Inhalable Endotoxin (EU/m^3)
1	Normal	0.17	2.76	5.37	3432.27
2		0.25	21.65	3.23	2674.80
3		0.39	1.09	6.93	1316.38
4		0.24	0.49	1.16	331.92
5		0.40	4.12	0.54	63.47
6		0.25	0.49	6.04	609.21
7		0.17	19.96	3.04	583.76
8		0.81	0.72	3.46	683.60
9		0.41	3.53	7.73	804.92
10		0.17	1.00	2.26	579.29
11	Intervention	0.00	1.00	2.38	4633.51
12		0.12	1.05	2.98	326.96
13		0.36	2.15	3.66	187.15
14		0.09	3.68	0.74	629.83
15		0.00	0.59	3.41	217.18
16		0.08	3.61	2.17	757.40
17		0.00	4.96	2.92	602.91
18		0.17	3.19	0.41	291.90
19		0.08	12.30	3.13	959.47
20		0.28	7.10	0.77	148.23

TABLE II. Personal Exposure Concentrations of Organic Dust and Endotoxin

	Normal[A] Mean (SD)	Intervention[B] Mean (SD)	p-value[C]
Respirable organic dust (mg/m^3)	0.25 (0.11)	0.12 (0.12)	0.01
Inhalable organic dust (mg/m^3)	3.98 (2.44)	2.26 (1.20)	0.14
Respirable endotoxin (EU/m^3)	5.58 (7.72)	3.96 (3.54)	0.88
Inhalable endotoxin (EU/m^3)	1108 (1089)	875(1348)	0.33

[A]"Normal" conditions consisted of washing the parlor four times per work shift.
[B]"Intervention" conditions consisted of washing the parlor eight times per work shift.
[C]Wilcoxon signed-rank test.

normal and intervention conditions. Relative humidity increased under the intervention condition. This increase may have contributed to the lower dust levels observed under intervention condition.

The lowest mean concentration for respirable dust was 0.25 mg/m^3 when the dairy parlor was cleaned under normal conditions and 0.12 mg/m^3 under intervention conditions (Table I). For inhalable dust, the mean concentration was 3.98 mg/m^3 under normal conditions and decreased to 2.26 mg/m^3 under intervention. These results suggest that cleaning the milking parlor may contribute to lower dust concentrations more frequently. Previous studies have also found similar dust concentrations reported in this study.[9,11]

Our results suggest high variability in inhalable dust exposure concentrations among these parlor workers. For inhalable dust concentration, the highest concentration was 7.73 mg/m^3, which was nearly double the concentration observed among nearly all other parlor workers. An exposure limit of 2.4 mg/m^3 for total dust has been recommended to prevent adverse work-related health effects in swine and poultry environments.[13,23] Some studies have suggested an exposure limit of 2.4–2.5 mg/m^3 for organic dust.[15] These results suggest that the parlor workers may be exposed to concentrations of organic dusts above recommended limits while performing routine tasks. However, additional research is needed, as recommendations for occupational exposure to organic dust were based on research from agricultural industries other than the dairy work environment.

Currently, no standards exist for endotoxin exposure; however, previous studies have suggested inhalation exposure above certain thresholds (300 EU/m^3 and 2400 EU/m^3)[24–26] could lead to lung disease among workers. In 1998, the Dutch Expert Committee on Occupational Safety and Health (DECOS) proposed an endotoxin exposure limit of 50 EU/ m^3.[27] Research in poultry industry has also associated significant pulmonary function decrement for endotoxin at 614 EU/m^3.[23]

The highest concentration of inhalable endotoxin was 4633 EU/m^3, which is above the suggested levels of 300 EU/m^3 and 2400 EU/m^3. A previous study suggested that the no observed effect level for ODTS or toxic pneumonitis for environmental endotoxin is 2000 EU/m^3.[24] Parlor workers in this study were exposed to endotoxin concentrations that may place them at risk for ODTS; however, additional exposure information is needed.

Study Limitations

This study had several limitations. Dust and endotoxin personal exposure estimates were measured among only 20 dairy parlor workers on one dairy farm. Therefore, the information learned from this study may not be representative of all work exposures or farms in the dairy industry. An increased sample size may allow the use of a more powerful parametric statistical test. Also, the sample variance may have contributed to the lack of statistically significant differences. However, we were able to observe a statistically significant difference in the exposure concentrations of respirable dust.

Task variability is another issue that may have impacted our results. Differences exist between how workers perform tasks in the dairy parlor. For example, a worker may perform a parlor work task in a manner that would generate more dust and endotoxin compared to other workers performing the same task. If present, this exposure variability may have been reduced by an attempt to sample the same workers across the experimental condition. However, given changing parlor work schedules, this approach was not optimally achieved in the study. Workers are typically trained to perform work tasks similarly to maximize productivity and work quality. Therefore, worker training may also reduce the effect of exposure variability due to workers performing similar tasks differently. Also, the number of cows milked per shift may vary. This variance would have little impact on the observed results of this study. The herd at this farm was approximately 2000 cows at the time of the study and varied little across the experimental condition.

Future Research

Limited information exists on the occupational exposure to inhalation hazards among workers in the dairy industry. Additional research assessing personal exposure to inhalation hazards in the dairy industry needs to be performed, and future work should focus on collaborations with dairy producers to test cost-effective solutions to identified inhalation hazards.

CONCLUSION

Our findings suggest increased cleaning efforts resulted in a statistically significant decrease in respirable dust exposure. The concentration of inhalable dust and endotoxin also decreased, although the decrease was not statistically significant. Additional cleaning efforts may be an effective intervention for reducing occupational exposure to dust among dairy parlor workers. The proposed intervention could be easily implemented on other dairy farms, as the equipment used is common among them.

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