Dust and Noise Exposure While Using a Portable Wood Dust Collector

Donna J.H. Vosburgh, MS, PhD, RS
Reid T. Barnhart
Connor Carrington
Morgan R. Drewek
Department of Occupational and Environmental Safety and Health, University of Wisconsin–Whitewater

Abstract **The use of a portable wood dust collector (PWDC) to reduce exposure to wood dust during sanding with a belt sander or sawing with a miter saw was studied and an assessment was conducted of the effect of this collector on noise exposure. This pilot study used Institute of Occupational Medicine (IOM) samplers to collect wood dust samples and personal noise dosimeters to measure noise exposure. The PWDC was used to study various setup configurations for sanding and sawing. Other variables of interest were wood type, PDWC filter type, and sandpaper use frequency. The setup configuration of a commercially available hood was an important factor in the inhalable dust exposure when using sanding ($p = .0001$) and also sawing ($p < .0001$). The PDWC did not increase the noise during either task. None of the variables of interest predicted the noise level while sanding with a belt sander ($p = .56$). The type of wood was a significant predictor of noise for sawing with a miter saw ($p = .01$). The time it takes to adjust the PDWC hood and how this additional task affects productivity should be assessed to further understand the effectiveness of this control strategy.**

Introduction

The American Conference of Governmental Industrial Hygienists (ACGIH) has established their threshold limit value for exposure to wood dust aerosol (WDA) to be 1 mg/m^3 (inhalable) for all tree species except western red cedar, which is 0.5 mg/m^3. These limits were established to protect workers from adverse health effects ranging from decreased lung function to adenocarcinoma (American Conference of Governmental Industrial Hygienists, 2015). Many workers, from manufacturing to industrial arts schoolteachers, are exposed to WDA (Teschke, Marion, Vaughan, Morgan, & Camp, 1999). Douwes and coauthors (2017) studied worker expo-

sure to wood dust in joineries and furniture factories and the percentage of workers who had exposures over the ACGIH recommendation was 37.5–100% at the joineries and 12.9–28.6% at the furniture factories.

Within the manufacturing sector, the use of a local exhaust ventilation (LEV) system influenced worker exposure to WDA (Brosseau et al., 2001; Schlünssen et al., 2008). An LEV system with an outside exhaust can be expensive to install and operating costs are high because replacement air must be tempered (McDermott, 2001). If an LEV system is not used, or if it is used incorrectly, not only does the woodworker creating the wood dust potentially have a greater exposure but also other workers

in the shop can be exposed to elevated background wood dust concentrations (Martin & Zalk, 1997). Schlünssen and coauthors (2008) found that workers in woodworking factories with <20 employees had higher dust exposures than those in larger facilities. These smaller facilities might lack an LEV system due to capital and operational costs.
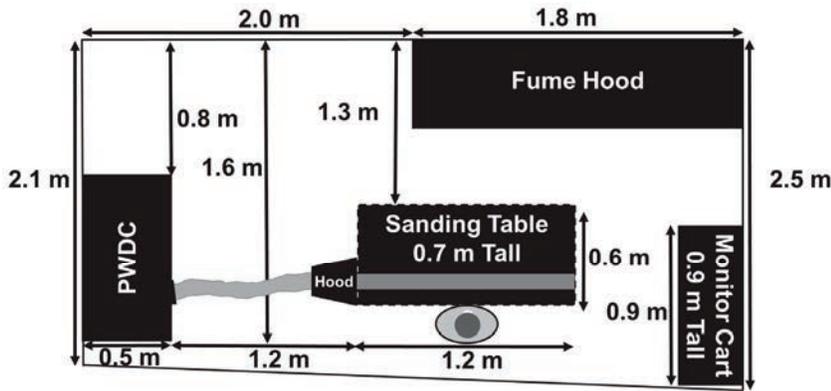
A portable wood dust collector (PWDC) could be a solution for small businesses that have high wood dust exposures. PWDCs are functionally similar to vacuums. A basic PWDC draws in the wood dust aerosol and passes it through the blower to a filter (either a bag or cartridge) and recirculates the cleaned air into the work area. Large wood particles fall off of the filter into a collection bag while the small particles are collected on the filter. PWDCs can also have cyclones or multiple filters. Little is known about the effectiveness of cartridge filters for woodworking PWDCs; however, research has been done with bag filters that found the bag filters were effective at reducing WDA when the wood dust was fed into the PWDC (Thorpe & Brown, 1998). Research is needed to evaluate PWDC effectiveness during actual woodworking tasks.

Currently, no studies are available that assess noise exposure from using a PWDC. As a PWDC is used only when a power tool is being used, the noise generated by that tool could outweigh the effect of the PWDC. If the power tool produces sound levels 10 dB greater than the PWDC, the worker's noise exposure might not be increased (Plog & Quinlan, 2012). Theoretical noise exposure levels could be calculated; however, most PWDCs for woodworking require operation of the unit before and after using the power tool. Even if the power tool sound pressure level was 10 dB greater than the PWDC,
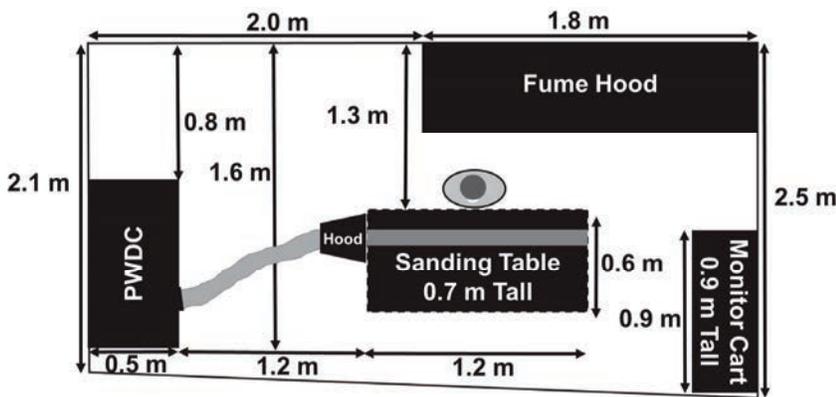
FIGURE **1**
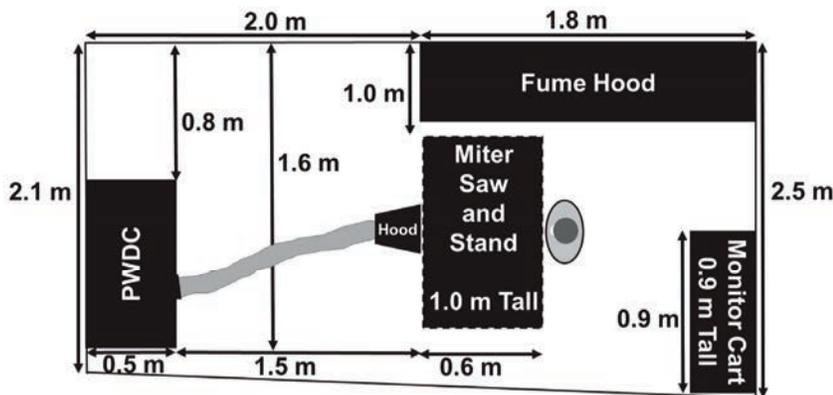
Sample Area Setup Configurations

A) Sanding Front of Stroke

B) Sanding Back of Stroke

C) Sawing With PWDC

PWDC = portable wood dust collector.

the extra running time for the PWDC could increase the overall noise exposure.

In this study, we examined the effectiveness of a PWDC during sawing with a miter saw and sanding with a belt sander. We also investigated the potential noise exposure due to PWDC use. The objectives of this study were to:

1. Determine if wood dust exposure was reduced using a commercially available PWDC, and if so, which setup configuration significantly reduced exposure.
2. Assess the influence of other variables such as wood type on the effectiveness of the PWDC.
3. Measure the effect of the PWDC on noise exposure.

Methods

We chose the Dust-Force 1.5 HP motor (JDS Company) PWDC for this study because it can incorporate either a bag filter or a cartridge filter. The selected filters were labeled by the manufacturer as a 1-μm bag filter and a 1-μm cartridge filter. The PWDC did not come with a hood attachment. We purchased a 0.31 m x 0.41 m WoodRiver hood with floor stand (WoodCraft) to attach to the PWDC. We used a 3.05 m flexible tube (3:1 compression ratio) with a diameter of 10.16 cm to attach the hood to the PWDC.

For both sawing and sanding, pine (a softwood) boards (5.1 cm x 10.2 cm x 122 cm nominal size) and oak (a hardwood) boards (2.5 cm x 10.2 cm x 122 cm nominal size) were used. Samples were collected in an area of the laboratory that was separated from the rest of the laboratory with a cotton cloth curtain (Figure 1). The curtained area was approximately 3.9 m x 2.1 m. The curtains were suspended 30 cm from the ceiling to the floor on a curtain rod made from PVC pipe, thus inhibiting air from entering the restricted area. There were no room HVAC ventilation inlets or outlets in the curtained area. Within the area was a fume hood that was not used during sampling. The same woodworker conducted the sawing and sanding for all sampling events.

Institute of Occupational Medicine (IOM) samplers connected to personal sampling pumps were used to collect inhalable wood dust samples. An M30 Mini-Buck calibrator (A.P. Buck, Inc.) was used to precalibrate and postcalibrate the flow rate of 2 L/min. The IOM sampler was placed in the breathing zone on the woodworker's right shoul-

der. The IOM samples were gravimetrically analyzed by an American Industrial Hygiene Association-accredited laboratory.

Prior to the initiation of sampling, airflow through a loaded PWDC was measured using a pitot tube traverse (McDermott, 2001). The loading was the maximum amount of wood dust that was anticipated during sampling and was less than one half the capacity of the PWDC. A duct was attached to the PWDC and the velocity was measured with a model 100.5 pitot tube traverse (red gage fluid). The wood dust loading in the collection bag did not reduce the air velocity. The filter was vacuumed only when we changed the filter or wood type. We turned the cartridge filter handle each sample per manufacturer's instructions.

While the WDA samples were collected, the noise exposure of the woodworker was determined using a 3M EDGE eg5 noise dosimeter. The dosimeter was programmed according to ACGIH criteria (Berger, Royster, Royster, Driscoll, & Layne, 2003) and precalibrated with a 3M QC-20 sound calibrator. Although the woodworker was right handed, the dosimeter was placed on the woodworker's left shoulder because the IOM sampler was on the woodworker's right shoulder. After completion of the dust sampling, the noise dosimeter was stopped, postcalibrated, and the data from the dosimeter were downloaded as 1-min measurements. The A-weighted equivalent-continuous sound level (L_{Aeq}) was calculated for the sampling time period after the 1-min noise levels from the dosimeter data were downloaded using the following equation (Berger et al., 2003):

$$L_{Aeq,T} = 10\log\left[\left(\tfrac{1}{T} \times \sum_{i=1}^{N}\left(\left(\tfrac{1}{60}\right) \times 10^{\left(\frac{Li}{10}\right)}\right)\right)\right]$$

where $L_{Aeq,T}$ is the A-weighted average noise level for the task of duration T where L_i is the 1-min noise level from the noise dosimeter.

Sanding

A Porter-Cable 352VS belt sander was used to sand the boards. The distance the board was sanded was 0.8 m, which was the mean sanding stroke length found by Thorpe and Brown (1994). The sander's speed option 6 and an 80-grit sandpaper belt were used for all samples. Each sandpaper belt was employed for a maximum of two samples before replacement and the order of sandpaper belt use (first or

second use) was recorded for each sample. The board was sanded on one side for 20 min, flipped over (1 min), and the other side of the board was sanded for an additional 20 min. For each minute of sampling, the board was sanded for 45 s followed by a respite of 15 s when no sanding occurred.

Before sampling, the thickness of the boards was measured at six locations (102 mm, 242 mm, 406 mm, 559 mm, 711 mm, and 902 mm). After the 41-min cycle was completed, the board was measured again at the six locations. The difference in wood volume/cycle was used to normalize the results to account for differences in pressure applied by the woodworker that could have influenced the amount of wood removed from the board and thus aerosolized. $C_{m(sand\ norm)}$ was the normalized concentration and it was calculated using the following equation:

$$C_{m(sand\ norm)} = C_m \times \frac{v_{wood(diff)}}{v_{wood(comp)}}$$

where $v_{wood(diff)}$ is the difference in volume of the wood before sanding and after sanding.

The measurements before and after sanding from the six locations on the wood were used to calculate the volume difference. $v_{wood(comp)}$ was the comparison wood volume difference and was the sample volume with the least volume removed. There were two values for $v_{wood(comp)}$, one for pine and one for oak. The comparison volume difference for pine was 319.8 cm³ and the comparison volume difference for oak was 119.3 cm³. All results from pine sanding were normalized to the pine comparison value and all results from oak sanding were normalized

to the oak comparison value. C_m was the concentration of the sample and was calculated with the following equation:

$$C_m = m/v$$

where m was the mass of the sample and v was the volume of the air sampled after it was corrected to normal temperature and pressure.

Four PWDC setup configurations were measured for sanding (Figure 1):
1. "Front of stroke" referred to when the hood was placed at the front of the stroke.
2. "Back of stroke" referred to when the hood was placed at the back of the stroke.
3. "General ventilation" referred to when the hood and tubing connecting the hood were disconnected from the PWDC and the hood and tubing were removed from the curtained area so the PWDC could function as a general ventilation unit.
4. "Without PWDC" referred to when the PWDC and hood were not used and were both removed from the curtain area.

The hood was placed 10.2 cm in front of the sanding stroke for the "front of stroke" configuration, and 31.8 cm behind the sanding stroke for the "back of stroke" configuration. For all setup configurations, the sawdust collection bag that came with the sander was used on the sander. The sawdust collection bag did not influence hood placement because the sawdust collection bag came out from the top of the sander at an angle.

Sawing

The same woodworker used a Makita LS1216L compound miter saw to cut boards one time

TABLE **1**

Sanding Multiple Linear Regression Results With Tukey–Kramer Multiple Comparison Test Results for Setup Configurations

Configuration Identification	Portable Wood Dust Collector (PWDC) Configuration	Model Fit Inhalable Dust Geometric Mean* (mg/m³)	Significantly Different Comparisons
A	Back of stroke	9.9	C, D
B	Front of stroke	14.0	D
C	Without PWDC	22.3	A
D	General ventilation	23.8	A, B

*The model fit exposures are for the task if the sanding belt was used a second time.

Sawing Multiple Linear Regression Results With Tukey–Kramer Multiple Comparison Test Results for Setup Configurations

Configuration Identification	Portable Wood Dust Collector (PWDC) Configuration	Model Fit Inhalable Dust Geometric Mean* (mg/m³)	Significantly Different Comparisons
A	With PWDC	3.0	B**, C**
B	General ventilation	9.2	A**, C
C	Without PWDC	16.4	A**, B

*The model fit exposures are for the task if the sanding belt was used a second time.
**Indicates inhalable dust geometric means that are significantly different with $p \leq .001$.

every 15 s for 80 min. The resulting pieces of wood were approximately 4 mm thick. Three PWDC setup configurations were measured for sawing (Figure 1):

1. "With PWDC" referred to removing the sawdust collection bag that came with the saw and placing the hood at the back of the saw next to the opening where the sawdust collection bag would have connected to the saw.
2. "General ventilation" referred to when the sawdust collection bag was left on the saw and the hood and tubing connecting the hood were disconnected from the PWDC and were removed from the curtained area so the PWDC could function as a general ventilation unit.
3. "Without PWDC" referred to when the sawdust collection bag was left on the saw and the PWDC and hood were not used and both were removed from the curtained area.

The sawdust collection bag that came with the saw was removed for the "with PWDC" configuration because it extended straight back from the saw approximately 23 cm. When the miter saw tilted to cut the wood with the sawdust collection bag on, it did not allow the PWDC hood to be close enough to the saw to function. To allow the PWDC hood to be close to the saw, the sawdust collection bag was removed. When the saw was used with the sawdust collection bag in place for the "general ventilation" and "without PWDC" configurations, the sawdust collection bag was emptied at approximately 35 min. Emptying the sawdust collection bag took 1 min and was not counted in the 80-min sampling period.

Data Analysis

A total of 80 IOM samples was used in the data analysis. All exposures were calculated after correcting for normal temperature and pressure. Four conditions were assessed: pine wood with bag filter, oak wood with bag filter, pine wood with cartridge filter, and oak wood with cartridge filter. Within each condition, we randomly assigned the order of PWDC setup configurations.

For each combination of wood/filter PWDC setup configuration, except for the "without PWDC" setup configuration, three samples were collected. Three samples of each "without PWDC" setup configuration were collected for the categories of pine wood with bag filter and oak wood with bag filter. Two samples of each "without PWDC" setup configuration were collected for the setup configurations of pine wood with cartridge filter and oak wood with cartridge filter—one randomly placed in the sampling order and one as the last sample. These "without PWDC" setup configuration samples served as a quality control verifying consistent sampling conditions in the curtained area. All of the "without PWDC" samples were within the allowed deviation, so we made the assumption that sampling conditions were consistent. We used all of the "without PWDC" samples in the data analysis.

Contemporaneous real-time aerosol concentrations were measured during sampling using a 3M EVM-7 photometer placed on a monitor cart (Figure 1). The photometer provided real-time assurance that there was consistent dust generation during the sampling period. The photometer data were not used in the analysis of the PWDC because

the sanding results could not be normalized. The process for normalizing the sanding IOM samplers could not be used with the monitor because the aerosol size range that the monitor measures does not match the inhalable size range an IOM sampler measures.

Statistical Analysis

We used multiple linear regression models to analyze the IOM results and the noise results. The variables of interest in the sanding model were PWDC setup configuration, wood type, filter type, and number of times the sandpaper belt was used. The variables of interest in the sawing model were PWDC setup configuration, wood type, and filter type. A post hoc Tukey–Kramer multiple comparison test identified the levels of model features that were statistically different. Statistical significance for all tests was evaluated at the 95% confidence interval level. Analyses were carried out using SAS version 9.4.

Results

The log transformed sanding and sawing IOM results were normally distributed, as determined by Shapiro–Wilk test (p = .90 and p = .22, respectively). The noise results were normally distributed as determined by Shapiro–Wilk test (p = .06 and p = .45, respectively). For sanding with a belt sander, the multiple linear regression model revealed that inhalable wood dust exposure of the task was significantly associated with PWDC setup configuration (p < .0001) and whether it was the first or second time the sandpaper belt was used (p < .0001).

Table 1 shows that placing the PWDC hood in the back of the sanding stroke (back of stroke) significantly reduced exposure compared with not using the PWDC or placing the PWDC in the room without a hood ("general ventilation"). Using the PWDC as general ventilation was not statistically different from using the sander without PWDC; this setup configuration also caused an increase in the model fit inhalable dust geometric mean that was not significant. The model estimated that using a sandpaper belt for the first time caused a 1.9 mg/m³ increase in exposure compared with using a sandpaper belt for the second time.

For sawing with a miter saw, the multiple linear regression model revealed that PWDC setup configuration was the only variable of

interest that was significantly associated with the task wood dust exposure ($p < .0001$). Having the PWDC functioning as a general ventilation unit significantly reduced inhalable wood dust exposure compared with sawing without the PWDC (Table 2).

None of the variables of interest predicted the A-weighted equivalent-continuous sound level that was produced during sanding ($p = .56$). The overall mean decibel level during sanding was 97.3 dB with a standard deviation of 0.8 dB. During sawing, the noise level was significantly associated with the type of wood ($p = .01$) and the mean differences between oak and pine were small (mean for oak = 93.9 dB, mean for pine = 92.9 dB). The PWDC setup configuration was not significant for sawing ($p = .07$), with a mean of 93.9 dB for "with PWDC," 93.3 dB for "general ventilation," and 93.0 dB for "without PWDC."

Discussion
The PWDC reduced woodworker exposure to WDA during the tasks of sanding with a belt sander and sawing with a miter saw. Not surprisingly, the PWDC created the greatest reductions when there was a hood that could take advantage of the inertial movement of the wood dust (Tables 1 and 2). There was also a significant reduction in exposure during sawing when the PWDC functioned as a general ventilation unit, whereas there was not a significant reduction—and in fact, a slight increase—in exposure when the PWDC was used as a general ventilation unit during sanding. Cutting wood and sanding wood create different-sized aerosol distributions (Vaughan, Chalmers, & Botham, 1990), which might have led to the difference in effectiveness as a general ventilation unit.

The effectiveness of the PWDC with the miter saw might be deceiving to woodworkers who have not been trained that the inhalable dust size is the dust size that causes health concerns. A miter saw creates not only inhalable dust but also wood dust with particle sizes that are larger and therefore not a health concern for workers. The "with PWDC" sawing setup configuration collects inhalable particles but does not effectively collect the larger wood particles that deposit around the saw. This housekeeping problem could lead some woodworkers to believe that the PWDC is not effective because they still have to clean the work area.

The sampling protocol for both sanding and sawing did not include 8-hr samples of continuous sawing and sanding but instead looked only at the results for the time of the task. Our study's protocol of a 40-min sample time for sanding would be equivalent to 8% of a workday and the 80-min sample time for the sawing would be equivalent to 17% of a workday. In many small woodworking shops, woodworkers do not spend eight continuous hours doing the same task and the amount of time spent on the tasks varies by the type of shop.

In a pilot study conducted by Brosseau and coauthors (2001), it was found that the time spent sanding with a hand power tool varied from 1% to 16% of a workday and the time spent sawing with a power tool varied from a 8% to 34% of a workday. In joineries, Douwes and coauthors (2017) found belt sanders were used 9% of the workday, whereas a miter saw was employed only 0.6% of the workday.

Another important aspect of any control strategy is cost. The PWDC with cartridge filter is more expensive than the PWDC with bag filter. This research found no difference in effectiveness, therefore the cheaper bag filter option would be sufficient for sanding with a belt sander and sawing with a miter saw. The longevity of the filters, however, was not addressed in this study and thus could influence the overall cost effectiveness of the bag filters.

Limitations
Although our study found that the PWDC reduced exposure to WDA, this conclusion is based on only two woodworking tasks under laboratory conditions. Additional research is needed to investigate the use of a PWDC with additional woodworking tools. The time it takes to adjust the PWDC hood or to move the PWDC affects productivity, which highlights another factor to investigate.

Conclusion
A PWDC is a potential low-cost solution for small businesses addressing the problem of WDA exposures. This solution does not increase noise exposure. The PWDC with the hood placed behind the sanding stroke significantly reduces the woodworker's exposure to WDA. For sawing, the WDA exposure was significantly reduced when the PWDC was used as a general ventilation unit. The decrease in WDA exposure was even greater when the hood was attached to the PWDC and placed in close proximity to the back of the saw. Both PWDC filter options are equally effective.

Corresponding Author: Donna J.H. Vosburgh, Associate Professor, University of Wisconsin–Whitewater, 800 West Main Street, Whitewater, WI 53190. E-mail: vosburgd@uww.edu.

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