Assessment of Particulates and Bioaerosols in Eastern Canadian Sawmills

AUTHORS
Caroline Duchaine[a]
Anne Mériaux[a]
Peter S. Thorne[b]
Yvon Cormier[a]

[a]Centre de Recherche, Hôpital Laval, 2725 Chemin Ste-Foy, Ste Foy, Québec, Canada, G1V-4G5; e-mail: duchaine@mediom.qc.ca;
[b]University of Iowa College of Public Health, Department of Occupational and Environmental Health, Iowa City, Iowa

The purpose of this study was to quantify and identify the airborne contamination in eastern Canadian sawmills. Seventeen sawmills were chosen to cover a wide range of size, geographic distribution, and wood species processed. Within each sawmill different work sites (debarking, sawing, sorting, or planing) were studied separately. Area sampling was performed for exposure assessment. Microbial contaminants were assessed with all-glass impingers 30 and six-stage Andersen microbial samplers; appropriate selective media and culture conditions for bacteria, thermophilic actinomycetes, molds, and yeasts were used. Inhalable dust, endotoxins, temperature, and humidity also were measured. *Penicillium* species were the most predominant molds with up to 40 different *Penicillium* species identified. Debarking was the working site most highly contaminated by molds, bacteria, and endotoxins ($p=0.0001$). At this working site mold levels reached a maximum of 1.5×10^6 CFU/m^3, whereas the median values for culturable bacteria and endotoxin were 21,620 CFU/m^3 and 1081 endotoxin units/m^3, respectively. Planing sites were the most highly dust contaminated (median: 3.0 mg/m^3) ($p < 0.05$). Sawmills of eastern Canada contain airborne biological contaminants that vary between working sites, and their microflora is different from that previously described in European sawmills.

Keywords: aerobiology, biological exposure, endotoxins, environmental molds, sawmills, wood dust

APPLIED STUDIES

Forestry is an important industry in Eastern Canada, employing about 12,000 workers in the Province of Quebec. Health risks such as lung cancer[1] and organic dust-induced respiratory diseases[2,3] are related to working in sawmills. Wood dust itself is associated with asthma[4-7] as well as irritant and allergic dermatitis, nasal mucosal irritation,[5,8] and nasal and other organ cancers.[1] Exposure to terpenes and other volatile compounds associated with pine trimming can reduce lung diffusing capacity and increase bronchial reactivity.[9,10]

Several European studies have analyzed the airborne microbiological contamination in sawmills.[5,11-13] Eduard and co-workers showed important amounts of airborne *Rhizopus* and *Paecilomyces* spores in Scots pine and spruce sawmills.[11] In the United Kingdom, *Penicillium*, *Trichoderma*, and *Aspergillus* were the mold genera most frequently found.[5] The bacterial content of wood also has been studied and reviewed.[12,14] Bacteria such as *Bacillus subtilis*, *B. cereus* var *mycoides*, and *B. pumulus*, as well as *Corynebacterium* sp. and *Clostridium* sp. are the most commonly found in timber.

Hypersensitivity pneumonitis and specific antibody production among sawmill workers has been reported in European studies.[11,15] In Norway the presence of antibodies against *Rhizopus microsporus* and *Paecilomyces variotii*, the predominant mold in the sawmills studied, correlated with exposures.[11] Specific IgG against *Rhizopus* sp. was demonstrated in another European study of wood trimmers,[16] and *Rhizopus* sp., *Paecilomyces* sp., and *Mucor* sp. were responsible for hypersensitivity pneumonitis and were the most common molds in Swedish sawmills.[2,17] Dykewicz and co-workers demonstrated precipitin production against *Paecilomyces* sp., *Rhizopus* sp., *Aspergillus niger*, *Aspergillus* sp., and *Penecillium* sp. among American lumbermen.[18]

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To date, there has been no published study performed in Eastern Canada to analyze bioaerosols in sawmills. Since the tree species and the climate are different from those of European countries, there may be substantial differences in concentrations and microbial species. Although pine, cedar, birch, and oak are sometimes used, spruce and fir account for the majority of timber processed in Eastern Canadian sawmills.

Before debarking and processing, timber is often kept outside in conditions that allow mold growth and bark deterioration. After being sawed, wood planks may be stored outside, prior to or after planing. The contamination to which the workers are exposed depends on a number of variables such as the presence of bark and its contamination, kiln utilization and temperature, and storage time before planing. Because of differences in lumber quality and quantity of dust produced, different work sites could have differing levels of air contamination.

The major aims of this study were (1) to evaluate aerosols and bioaerosols in sawmills, (2) to study the influence of work sites (or job location) and geographical regions, and (3) to speciate the sawmill fungal microflora and describe the predominant contaminants.

MATERIALS AND METHODS

Sawmill Selection

Air sampling was performed at 17 sawmills in 4 geographical regions of Quebec. Different geographic regions were selected to create a good sample of the various climatic conditions of this large Eastern Canadian province. Each of the work sites present (debarking, sawing, planing, and sorting) were evaluated separately. Sawmills were grouped according to their size as defined by the number of workers. One small (<50 workers) and two large (50–125 workers) spruce/fir sawmills were chosen for each region. Since the hardwood processing plants were more uniform, their size was not taken into account. Air sampling was stratified by season (May–June, July–August, September–October) and the sawmills were randomly assigned to these time intervals. Samplings were performed from May through October of 1996 and 1997.

Sawmill Characteristics

Logs usually were kept outdoors on the soil before being brought to the sawmill. Outdoor storage could vary from days to months depending on the sawmill, the season, and the quantity of stocked wood. Debarking was performed mechanically on dry or wetted logs either indoors or outdoors. Logs were then conveyed to the sawing site, where they were cut into rough planks and trimmed. Workers operating the saws stood near the sawing sites, where they cleared jams and cleaned the saws and surrounding area. From there, the wood was sorted and piled (sorting site) and sent outside for a few hours to several weeks. The wood was then planed or kiln dried (80°C) prior to planing. All these sites (debarking, sawing, sorting, and planing) could be in the same building or in different places. In each sawmill studied, there were between two and four work sites available for sampling. Outside work sites were not sampled.

For two sawmills (one birch and one cedar), the wood was processed differently. At the birch sawmill, timbers were "unrolled" after debarking. The unrolling replaced the sawing. A thin veneer lathe was produced by a blade pressed on a rolling debarked timber. There was usually still some bark left on the logs at the beginning of the unrolling. These sheets were then sawed to narrower strips. For the cedar sawmill the wood was cut into shingles, which were piled manually.

Environmental Sampling

All stationary environmental sampling was performed on a table 1 m above the floor, as near the work site as possible and away from ventilation sources. It is important to note that sampling efficiency may be dependent on mounting parameters.

Inhalable Dust (Dry Weight)

Inhalable dust samples were collected in triplicate for at least 6 hours. Preweighed 25-mm PVC filters (0.8 μm), housed in horizontally positioned IOM cassettes (SKC, Eighty-Four, Pa.), were used with personal sample pumps (SKC, Dur-Pro, Brossard, Canada) calibrated at 2.0 L/min with a Kurz flow meter (Instruments Inc., Carmel Valley, Calif.). Filters were desiccated in an oven (60°C) and weighed until they reached a constant weight, under controlled atmosphere to avoid rehydration. Control filters were brought on the sampling site, but were not subjected to sampling. The cassettes used had a 50% efficiency at 100 μm diameter; their collection efficiency approximates the inhalable curve. Inhalable dust samples were not collected for the first seven sawmills.

Environmental Analyses: Culturable Microorganisms and Endotoxins

Culture Media

Tryptic-soy agar (TSA) (Difco, Detroit, Mich.) supplemented with cycloheximide (500 mg/L) was used for the isolation of total mesophilic bacteria and thermophilic actinomycetes. Half-strength nutrient agar (1/2N) (Difco) also was used for thermophilic actinomycetes. Sabouraud dextrose agar (SDA) (Difco), rose bengal agar (RB) (Difco), and Czapek solution agar (CZA) (Difco) supplemented with chloramphenicol (50 mg/L) were used for mold cultures. Three different culture media were used for molds to recover the widest range of species possible. Yeasts also were recovered on SDA and RB. All media were sterilized at 121°C for 10 min.

Air Sampling

For air sampling, samplers were placed on a table 1 m above the floor, as near the work site as possible and away from ventilation sources. Two types of air samplers were used at each sampling site: 3 six-stage Andersen microbial samplers (AMS) (Grasby Andersen, Atlanta, Ga.) and 3 all-glass liquid impingers-30 (AGI) (Ace Glass Inc., Vineland, N.J.). The AMS were operated at 28.3 L/min. Sampling times were 20 min for TSA and 1/2N for thermophilic actinomycetes, 1 min for TSA for bacteria, and 30 sec for SDA, RB, and CZA. The three AGIs were loaded with 20 mL of sterile 0.85% saline solution and were sampled for 16 min at a flow rate of 12.5 L/min. Control samples were collected outside, 1 to 5 km upwind from the sawmill.

Sample Analysis

TSA and 1/2N from AMS were incubated at 52°C for 5 to 7 days for thermophilic actinomycetes recovery and at 30°C for 48 hours for mesophilic bacteria. SDA, RB, and CZA AMS plates were incubated at 30°C for 7 to 10 days.

After sampling, each of the remaining AGI solutions were measured and combined with 10–13 mL of washing solution comprised of sterile saline solution containing 0.1% Tween 80 to yield a final sample volume of 30 mL containing about 0.03% Tween 80. Three 1-mL samples of each 30 mL AGI solution were serially

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TABLE I. Sawmill Numbers, Regional Distribution, Wood Species, Number of Workers, and Sampling Date

	Southeastern Quebec	Southwestern Quebec	Northwestern Quebec	Northeastern Quebec
Spruce/fir				
Sawmill no. (no. employees)	17 (47)	1 (15)	15 (37)	12 (28)
Sampling date	10/97	6/96	9/97	7/97
Kiln presence	no kiln	no kiln	kiln[B]	no kiln
Sites[A]	De/Sa/Pl	De/Sa/So/Pl	Sa/Pl	De/Sa
Sawmill no. (no. employees)	14 (85)	8 (83)	11 (71)	10 (114)
Sampling date	8/97	4/97	6/97	6/97
Kiln presence	no kiln	kiln (88°C)	kiln[B]	no kiln
Sites[A]	De/Sa/Pl	De/Sa/So/Pl	De/Sa/Pl	De/Sa/So/Pl
Sawmill no. (no. employees)	16 (83)	2 (99)	9 (89)	66 (119)
Sampling date	10/97	7/96	5/97	10/961
Kiln presence	no kiln	no kiln	kiln (88–93°C)	kiln[B]
Sites[A]	De/Sa/Pl	De/Sa/So/Pl	De/Sa/Pl	De/Sa/So/Pl
Oak				
Sawmill no. (no. employes)		13 (24)		
Sampling date		7/97		
Kiln presence		no kiln		
Sites[A]		Sa/So		
Birch				
Sawmill no. (no. employees)	4 (19)		5 (86)	
Sampling date	8/96		9/96	
Kiln presence	no kiln		no kiln	
Sites[A]	De/Sa		De/Sa/Un	
Pine				
Sawmill no. (no. employees)			3 (110)	
Sampling date			7/96	
Kiln presence			kiln[B]	
Sites[A]			Sa/So/Pl	
Cedar				
Sawmill no. (no. employees)		7 (78)		
Sampling date		10/96		
Kiln presence		no kiln		
Sites[A]		Sa/Pl		

[A]De = debarking; Sa = sawing; So = sorting and Pl = planing; Un = unrolling.
[B]Temperaure (°C) unknown.

diluted to a 10^{-5} dilution. One hundred microliters of the dilutions (10^{0} to 10^{-3}), as well as 0.5 and 1 mL of the nondiluted AGI liquids, were plated on TSA, 1/2N, SDA, RB, and CZA and cultured as described in previous paragraphs.

Bacteria, thermophilic actinomycetes, and mold colonies were counted, and all macroscopically distinct mold colonies were isolated on SDA for later identification. For *Penicillium* species, John I. Pitt's guide for *Penicillium, Talaromyces* and *Eupenicillium* genera identification was used.[19] A reference manual was used[20] for other mold identification.

Endotoxins from AGI samples were measured using the *Limulus* amoebocyte lysate (LAL) assay endpoint chromogenic test (Associates of Cape Cod, Woods Hole, Mass.). Samples were frozen in borosilicate tubes prior to analysis. They were thawed, diluted, and an inhibition/enhancement test was performed prior to measurement. Controls were obtained with sterile saline solution with which sterile AGI were washed for several minutes. Control values were subtracted from the sample values.

Statistical Analysis

Exposure variables were tested to determine whether they were normally or lognormally distributed. Work sites (debarking, sawing, planing, and sorting) were compared using a Wilcoxon rank sum test. Data from bacterial counts were analyzed using a oneway analysis of variance with nontransformed values as normality and variance assumptions were met. Posteriori comparisons were performed with Scheffe's method. Relationships between parameters were expressed with Spearman's correlation coefficients. All reported p-values are two-sided. The results were considered significant if p-values were <0.05. The data were analyzed using SAS software (SAS Institute Inc., Cary, N.C.).

RESULTS

Table I shows the sawmill characteristics including regional distribution, wood species processed, number of workers, and sampling date. This table also shows information on the use of a kiln and the sites sampled in each mill. Exposure concentrations observed in the 12 spruce/fir sawmills are summarized in Table II, and those for the other sawmills are given in Table III. Although the single highest value measured was at debarking, median concentrations were highest at planing and sawing. Endotoxin analyses show that planing sites had lower contamination than debarking and sawing. Culturable organisms were measured using AGI and AMS methods; all nonconfluent AMS plates were

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TABLE II. Environmental Contaminant Concentrations at the 12 Sawmills Processing Spruce and Fir*

Spruce/Fir Sawmills	Dust mg/m³†	Endotoxin (EU/m³)	Culturable Microorganisms, CFU/m³				
			Molds/RB	Molds/SDA	Molds/CZA	Thermophilic Actinomycetes	Bacteria
Debarking	^{a}1.14 (0.64–5.15)	^{a}1081 (277–1.7×10^4)	^{a}8167 (1250–1.7×10^6)	^{a}1.05×10^4 (950–1.7×10^6)	^{a}6500 (600–2.1×10^6)	4 (0–74)	^{a}2.16×10^4 (9155–1.12×10^5)
Sawing	^{ab}2.07 (0.10–3.70)	^{ab}652 (219–3094)	^{b}3100 (0–1.3×10^6)**	^{ab}5100 (106–2.5×10^6)	^{b}1800 (0–1.3×10^6)	2 (0–28)	^{ab}2.02×10^4 (3944–7.66×10^4)
Sorting	^{b}1.30 (0.60–1.54)	^{c}335 (124–536)	^{b}5704 (800–9600)	^{b}3000 (845–9150)	^{b}1300 (845–1.1×10^4)	3 (0–4)	^{b}6831 (915–1.78×10^4)
Planing	^{a}2.73 (0.82–4.40)	^{bc}432 (151–3144)	^{b}1900 (423–2.4×10^5)	^{ab}2500 (211–1.4×10^5)	^{ab}2400 (0–1.4×10^4)	7 (0–42)	^{ab}1.06×10^4 (845–1.40×10^5)

† Different letters express statistically significant differences between counts. Example: dust values are different in debarking (a) and sorting (b) but not sawing (ab). Also, sorting dust values (b) are not different from sawing (ab), but differ from debarking (a) and planing (a). Comparisons were performed within a same column.
*Median and range (in parentheses) are shown.
**The ⟨⟨0⟩⟩ value indicates a count lower than the detection limit.

kept for analyses. AGI was used only when AMS were confluent and colony could not be counted. For bacteria, 47 sites out of 51 were counted from AMS. Molds were more frequently counted on AGI plates (43/51 for CZA, 42/51 for SDA, and 47/51 for RB). All thermophilic actinomycetes were counted from AMS plates.

Mold Identification

Plates that were used to quantify work site molds also were used to identify molds at the genus or species level. Each colony that was morphologically different on either AMS or AGI was isolated on SDA, purified, and kept on slant agar at 4°C until identification. A total of 1700 strains were identified. Table IV lists the most frequently isolated molds and their frequency in all the 50 working sites (excludes unrolling). Those species appearing at half or more of the work sites were *P. spinulosum, P. myczinski, P. fellutanum,* and *Eupenicillium* sp. *P. myczinski* was the predominant mold in 11 of the work sites and *P. spinulosum* dominated in 7. *P. rugulosum* (y) includes colonies showing all cultural identifying characteristics of *P. rugulosum* (*Biverticillium* subgenera, *Simplicium* section, *Islandica* series) according to penicilli and growth morphologies but showing a greater amount of yellow mycelium than expected. Also, some strains of *P. rugulosum* were difficult to differentiate from *P. glabrum*. *P. rugulosum* could therefore include some *P. glabrum* strains.

The different correlations found between environmental contaminants are the following: for spruce/fir sawmills, debarking sites show a positive correlation between dust level and molds ($p=0.005$, $r_s=0.7$). Dust levels correlate with endotoxins in the sorting sites ($p=0.03$, $r_s=0.8$). At planing sites, bacteria correlate positively with endotoxins ($p=0.01$, $r_s=0.8$). For all parameters, the effect of the size of the sawmill and geographical region

TABLE III. Environmental Contaminant Concentrations at Sawmills Processing Pine, Birch, Cedar, or Oak*

Wood Species	Working Sites	Dust (mg/m³)	Endotoxin (EU/m³)	Culturable Microorganisms, CFU/m³				
				Molds/RB	Molds/SDA	Molds/CZA	Thermophilic Actinomycetes	Bacteria
Pine sawmill (n = 1)	sawing	—^{A}	2.09×10^3 (593)	3.38×10^4 (1.76×10^3)	3.47×10^4 (1.10×10^4)	—	2 (–)	4.13×10^5 (1.53×10^5)
	sorting	—	2.18×10^3 (311)	2.23×10^3 (306)	5.20×10^3 (200)	2.50×10^3 (173)	2.5×10^3 (173)	1.97×10^3 (–)
	planing	—	1.76×10^3 (980)	7.67×10^3 (9.87×10^3)	400 (0)	500 (400)	500 (400)	2.25×10^3 (–)
Birch sawmills (n = 2)	debarking	—	985 (380)	2.13×10^5 (1989)	2.83×10^3 (2648)	2.11×10^3 (2274)	9 (0)	2.15×10^5 (666)
	sawing	—	993 (530)	645 (179)	1.51×10^3 (1300)	560 (351)	11 (10)	9.50×10^3 (3938)
	unrolling (n = 1)	—	323 (55)	3.00×10^4 (8.66×10^3)	2.40×10^4 (6.00×10^3)	—	1000 (–)	5.58×10^4 (–)
Cedar sawmill (n = 1)	sawing	—	1122 (90)	3167 1258	3000 (1000)	5000 (–)	133 (–)	15634
	planing	—	412 (76)	183 189	634 (–)	493 (–)	314 (–)	704
Oak sawmill (n = 1)	sawing	2.134 (1.787)	1173 (598)	3300 (2121)	2450 (106)	4000 (1131)	14 (–)	7394
	sorting	0.086 (0.067)	5944 (5231)	1467 (351)	3233 (814)	1767 (749)	2 (–)	2183

*Mean and standard deviation in parentheses. Absence of a standard deviation means that the value was obtained from a single count.
^{A}Not available (site not present or not sampled or data not available).

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TABLE IV. Frequency of Appearance of Specific Molds at Sawmills from the 50 Sites Sampled*

Taxa	Number of Sites Where Present (Number of Sites Where Predominant)	% of Sites Where Present (% of Sites Where Predominant)
P. crustosum	12 (1)	24 (2)
P. fellutanum	26 (4)	52 (8)
P. glabrum	11	22 (0)
P. myczinski	32 (11)	64 (22)
P. raistrickii	22 (1)	44 (2)
P. rugulosum	20 (1)	40 (2)
P. rugulosum (*y*)	19 (1)	38 (2)
P. spinulosum	37 (7)	74 (14)
P. waksmanii	16 (1)	32 (2)
Penicillium sp.	25 (3)	50 (6)
Eupenicillium sp.	25 (1)	50 (2)
Trichoderma sp.	23 (4)	46 (8)

*Unrolling site was not included.

(southeast, southwest, northeast, and northwest Quebec) were measured but were declared not statistically significant (p-values >0.25).

The three culture media used for fungi quantitation showed that debarking sites were the most highly contaminated spruce/fir sawmill sites ($p=0.0001$ for RB values). Debarking sites were also the most highly contaminated with bacteria and endotoxins ($p < 0.05$). Air sampling at 17 sawmills distributed across Quebec revealed dust concentrations ranging from 0.10 to 5.15 mg/m^3, whereas the planing sites were the most highly contaminated with dust ($p < 0.05$). Levels of thermophilic actinomycetes were very low (median from 2 to 7 CFU/m^3) in every site. The presence of a kiln did not increase thermophilic bacteria contamination. Molds belonging to the genera *Penicillium* were by far the most predominant. *P. myczinskii, P. raistrickii, P. spinulosum* and species showing teleomorph state belonging to *Eupenicillium* sp. were predominant contaminants. *Trichoderma* sp. was the most commonly recovered nonpenicillium genus.

DISCUSSION

The nature of the contaminants found in the Eastern Canadian sawmills seems very different from those of studies performed mostly in Europe, where *Rhizopus* sp. and *Paecilomyces* sp. were found. In the current study very few *Rhizopus* sp. and *Paecilomyces* sp. were recovered. In a previous study it was reported that these molds were recovered at higher temperature (40°C), but since these genera grow very well at 30°C,[20] they should have been recovered if they were present. Also, since only few studies have been performed in spruce-fir sawmills, the difference in the nature of airborne microflora could be explained, at least in part, by the difference in tree species.

The most highly contaminated sawmill was a spruce/fir sawmill. Debarking and sawing sites showed viable molds concentrations of 1.75×10^6 CFU/m^3 (on SDA) and 1.83×10^6 CFU/m^3 (on CZA), respectively. At both sites, *P. myczinskii* was the most predominant and represented up to 46% of the fungal contaminants (sawing site). This mold has not been found in significant amounts in other working environments.

Halpin and co-workers studied the aeroallergen concentration in a sawmill. The highest concentration of culturable molds measured was about 1.70×10^4 CFU/m^3 at the bark stripper area (debarking).[5] The concentrations found in the current study in Eastern Canadian sawmills were comparable to those described by Halpin and co-workers (Tables 2 and 3). The pine sawmill was one of the most highly contaminated with bacteria. The levels found at the sawing site reached 4.13×10^5 CFU/m^3. It was surprising to find these large quantities of bacteria in a sawing site since the bark was no longer present except in small quantities. The debarker was out of order at this time of the study; old debarked timbers were sawed: the storage condition prior to sawing or debarking could have created conditions allowing excessive bacterial growth. The thermophilic actinomycetes counts in the sorting site of this sawmill were also the highest found in the 17 sawmills (2.5×10^3 CFU/m^3) and were far from the median or mean values of the other sawmills. These were generally below 10 CFU/m^3. Molds also were found in high concentrations in the pine sawmill (3.38×10^4 CFU/m^3). The lower kiln drying temperature (71°C) in this sawmill, surprisingly, did not increase thermophilic actinomycetes counts even if this temperature is close to their growing conditions. European studies have previously shown that *Thermoactinomyces vulgaris* (a thermophilic actinomycete) and *Aspergillus* sp. may be responsible for allergic alveolitis in sawmills.[21] Since thermophilic actinomycete levels were generally very low, these microorganisms are unlikely to cause this disease in Eastern Canadian sawmills.

Due to methodologic differences, dust concentrations cannot be compared directly with American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit values (TLV®) (5 mg/m^3 for soft woods and 1 mg/m^3 for hard woods such as oak and birch). In this study the practice of allowing filter weights to stabilize at 60°C prior to weighing would underestimate dust concentrations compared with the ACGIH method. The highest dust concentrations measured in this study were obtained in two spruce/fir sawmills: 5.15 mg/m^3 for the debarking site of a sawmill and 4.14 mg/m^3 at the planing site of another mill. These are dry weights, and since the water content of wood dust may reach very high values (>50%), these samples both exceeded ACGIH criteria. The dry dust level in the oak sawmill (2.13 mg/m^3) was twice the TLV for hard wood. Therefore, the wet weight would have been at an even greater exceedance.

For spruce/fir sawmills, dust and mold concentrations correlated only in debarking sites ($p=0.005$, $r_s=0.7$). The dust concentrations at these sites are likely to be more contaminated by molds, since molds are very abundant in bark. In most of the sawmills the debarking operator was sitting in an isolated cabin. Thus, the operator was probably better protected against dust and molds exposure than other workers.

Dust concentrations correlated well with endotoxins in the sorting sites ($p=0.03$, $r_s=0.8$), and dust levels at these sites were low (median value of 1.30 mg/m^3). Therefore, dust exposure correlates very poorly with the other contaminants that could be involved in respiratory reactions among workers (molds, bacteria, endotoxins). During an industrial hygiene evaluation, dust exposure assessment should not be considered as a surrogate for exposure to microorganisms in sawmills.

Endotoxin levels were very high in some environments. The highest value was found in the debarking site of a spruce/fir sawmill (1.70×10^4 EU/m^3), but very high values were found in other sites as well (Table II). To the authors' knowledge, no environmental studies in sawmills have reported such high endotoxin levels.[22] The presence of bark that should support the growth of

APPLIED STUDIES

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microorganisms may be responsible for the higher endotoxin levels. In this study a very good correlation was found between bacteria and endotoxins ($p=0.01$, $r_s=0.8$) at planing sites in spruce/fir sawmills. At this working site a gram-negative bacterial population is likely to be more important than a gram positive one, even if the overall concentration may be lower.

CONCLUSION

Eastern Canadian sawmills contain an airborne microflora that is different from that described in European countries. *Penicillium* species are by far the most important fungi found, with concentrations reaching high levels in some working sites: the levels found reached values as high as some dairy barns or swine buildings.[23,24] Debarking sites were the most highly contaminated by molds, endotoxins, and bacteria, and significant differences were found between these sites and one or more other sites for spruce/fir sawmills. The concentrations and mold taxa reported in this study support the need to evaluate the effects of these airborne contaminants on the respiratory health of exposed workers.

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