

Saw Filers Exposed to Cobalt and Other Metals:

Determinants of Exposure

and Respiratory Health Evaluation

April 1993

Final Report to Participating Sawmills
and
the Workers' Compensation Board of B.C.

Kay Teschke¹, Susan M. Kennedy^{1,2}

Stephen A. Marion¹, Moira Chan-Yeung², Marielle van Zuylen³, John Lea¹

Teresa Switzer¹, Kent Thompson², Juri Oja²

¹ Department of Health Care and Epidemiology
University of British Columbia
Vancouver B.C., V6T 1W5

² Respiratory Division
Department of Medicine
University of British Columbia
Vancouver B.C., V6T 1W5

³ Wageningen Agricultural University
Wageningen, The Netherlands

Acknowledgments

We would like to extend our appreciation to the participating sawmill companies and employees for their co-operation and assistance throughout this study. We would also like to thank Bob Stewart and the Workers' Compensation Board Laboratory for performing the analyses of the air samples and coolant samples. Many individuals, too numerous to mention, made helpful comments about the preliminary results of this study which have helped us to refine the final report.

This research was supported in part by a grant from the Workers' Compensation Board of British Columbia.

Table of Contents

Summary: Industrial Hygiene Assessment	i
Summary: Respiratory Health Assessment	iv
Recommendations: Industrial Hygiene Assessment	vi
Recommendations: Respiratory Health Assessment	viii
Recommendation: Exposure Standard for Cobalt	ix
1.0 Introduction	1
2.0 Background	1
2.1 Composition of saw tip metals	1
2.2 Potential means of exposure of saw filers to cobalt and other metals	3
2.3 Health effects of cobalt exposure	4
2.3.1 Hard-metal pneumoconiosis	4
2.3.2 Cobalt asthma and airflow obstruction related to cobalt	5
2.3.3 Lung health effects of cobalt dissolved in machining fluids	5
2.4 Health effects of other metals which may be present in saw filing	6
3.0 Methods	7
3.1 Participating sawmills	7
3.2 Industrial hygiene measurements and analyses	7
3.2.1 Personal air samples	7
3.2.2 Potential determinants of exposure	7
3.2.3 Bulk samples of coolants	8
3.2.4 Exposure data summarization and statistical analyses	9
3.3 Respiratory health assessment	11
3.3.1 Subjects 11	
3.3.1.1 Determination of eligible study participants	11
3.3.1.2 Participant recruitment	11
3.3.2 Questionnaire administration	12
3.3.3 Lung function testing	12
3.3.4 Allergy skin tests	13
3.3.5 Data handling and analysis	13
3.3.6 External comparison population	15
4.0 Industrial Hygiene Results 16	
4.1 Characteristics of the participating sawmills	16
4.2 Personal exposure levels	16
4.3 Patterns and determinants of metal exposures	20
4.3.1 Cobalt air concentrations	21
4.3.2 Chromium air concentrations	23

Table of Contents

4.3.3	Iron air concentrations	24
4.3.4	Lead air concentrations	25
4.3.5	Cadmium air concentrations	25
4.3.6	Silver air concentrations	26
4.4	Bulk samples of coolants	26
4.5	Ventilation at machines in the saw filing rooms	28
5.0	Respiratory Health Assessment Results	32
5.1	Study participation	32
5.2	Characteristics of study participants	33
5.2.1	Sawfilers compared to bus mechanics - demographics	33
5.2.2	Demographic characteristics among saw filers, according to different job titles	34
5.3	Reported current and historical job tasks among sawmill study population	34
5.4	Respiratory symptoms	36
5.4.1	Simple comparison of symptoms rates between saw filers and bus mechanics	36
5.4.2	Comparison of work and demographic predictors of respiratory symptoms	37
5.5	Lung function test results	38
5.5.1	Explanation of test results	38
5.5.2	Lung function among saw filers compared to bus mechanics	39
5.5.3	Comparison of work and demographic predictors of lung function results 40	40
5.6	Other possible predictors of respiratory health outcomes	43
5.7	Changes in lung function over one work shift in relation to measured exposure to metals	44
6.0	Relationships Between Exposures and Respiratory Health Effects	45
6.1	Qualitative exposure-response relationships	45
6.2	Quantitative exposure-response relationship for cobalt	46
6.3	Evaluation of the proposed Permissible Concentration for cobalt	47
7.0	Epilogue	49
7.1	Information from the study mills	49
7.2	Information from University of British Columbia medical colleagues	50
8.0	References	52
Appendix A:	Forms used in industrial hygiene assessments	
Appendix B:	Letter of introduction to study participants	
Appendix C:	Respiratory symptoms questionnaire	

Summary: Industrial Hygiene Assessment

Results and Conclusions

1. The study was conducted in eight coastal sawmills. Most of these mills contacted us to volunteer

participation. All eight mills used saw steel as saw tips, seven used tungsten carbide tips, and six mills used stellite tips. Each mill was visited on four days, or pairs of days, at least one month apart in the summer and fall of 1991.

2. Industrial hygiene assessments included 278 personal total-metal-in-air samples (1 to 4 samples taken on each of 112 saw filing room employees), analyzed for 22 different metals; 73 samples of coolant from wet grinding machines, analyzed for 23 metals; and testing of 196 local exhaust ventilation systems.
3. Levels of total airborne metals in the saw filing rooms were generally low. Most of the 278 air samples did not have detectable levels of many of the 22 metals measured (the detection limits were less than 1/100th of the lowest exposure standard for almost all the metals).

Of the 22 metals analyzed, six metals were considered of greatest interest because, in samples with detectable levels, the average concentrations were more than 1/20th of the lowest exposure standard (ACGIH Threshold Limit Value or WCB Permissible Concentration). These metals were:

- cobalt, 59 samples greater than the detection limit, average = 0.0098 mg/m³
- chromium, 92 samples greater than the detection limit, average = 0.0042 mg/m³
- iron, 277 samples greater than the detection limit, average = 0.051 mg/m³
- lead, 39 samples greater than the detection limit, average = 0.014 mg/m³
- cadmium, 10 samples greater than the detection limit, average = 0.0069 mg/m³
- silver, 9 samples greater than the detection limit, average = 0.0042 mg/m³

Three of these metals had at least one air sample with a concentration above the TLV or PC:

- cobalt: 3 samples greater than the TLV of 0.05 mg/m³, and 1 of these greater than the WCB PC of 0.1 mg/m³
- chromium: 2 samples greater than the WCB PC of 0.05 mg/m³ for chromium VI
- silver: 1 sample greater than the WCB PC of 0.01 mg/m³

Even for these metals, however, exposures of individual saw filers averaged over all the sampling days were all below the exposure standards.

4. Increases in cobalt air concentrations were related to the following operations (in order from greatest to least exposure):
 - grinding tungsten carbide tips at a wet grinder
 - grinding tungsten carbide tips at a dry grinder
 - heating stellite

The contribution of heating stellite to cobalt air levels was no longer apparent when three outliers were removed from the analysis, therefore the impact of this activity is not certain. Tungsten carbide wet grinding machines had very high average levels of cobalt in their coolants, and these machines were often not

ventilated. Stellite wet grinding machines had much lower levels of cobalt in their coolants, despite the fact stellite contains more cobalt than tungsten carbide (50 - 63% versus 2 - 30%).

Heating stellite rather than heating tungsten carbide may increase cobalt levels because stellite tips are usually welded to the saw body whereas tungsten carbide tips are soldered, a much lower temperature heating process.

5. About 33% of samples had detectable exposures to chromium. Increases in chromium exposure were related to the following jobs or operations (in order from greatest to least exposure):

- working as a knife grinder
- heating stellite
- heating saw steel

Chipper knives have a chromium content of about 9%, considerably less than the 23 - 33% found in stellite, and as expected, there were lower concentrations of chromium in knife grinding coolants than in stellite grinding coolants. However, knife grinding produced higher chromium exposures. An explanation for this may be that knife grinders spend more time in the vicinity of their grinding machines than employees tending stellite grinding machines. In addition, most of the knife grinding machines were not ventilated. Heating stellite likely produced greater chromium exposures than heating saw steel because of the higher concentrations of chromium in stellite than saw steel (< 1%).

6. Exposures to the other four metals of interest may be partially explained as follows.

- Iron is present in both saw and knife steels as well as many other materials used in the filing rooms. Every saw filing room employee was exposed, but levels were generally low compared to exposure standards.
- Only 12% of air samples had detectable lead levels. Most of the exposed individuals worked with lead-based babbitt. Babbitt areas had a high proportion of ventilation systems rated "poor".
- Only 3.6% of samples had detectable cadmium concentrations. Most of the exposed individuals soldered carbide tips with silver solder.
- Only 3.2% of samples had detectable silver levels. Most of the exposed employees performed either silver soldering or circular saw grinding during the sampling period.

Summary: Respiratory Health Assessment

Results

1. Respiratory health evaluation was carried out among 118 saw filing tradesmen (saw filers) from 8 sawmills, using standardized techniques. The participation rate was 90%. The study was designed to measure respiratory health outcomes, not other possible health effects of exposures in these workplaces.
2. Compared to an external population (bus mechanics), studied using the same methods and equipment, saw filers in this study reported approximately twice the prevalence of phlegm production and wheezing ($p < 0.01$), and 3 times the prevalence of work-related symptoms of cough, phlegm, ($p < 0.001$) and wheezing ($p < 0.05$). They also had significantly lower average levels for the lung function variables MMF ($p = 0.06$), and FEV1/FVC ($p < 0.05$), compared to the external population.
3. Stellite welding in the current job was associated with a 5-fold increase in nasal symptoms and a 3-fold increase in work-related cough (both $p < 0.05$) compared to saw filers not performing this task. Adjustment for this task did not fully explain the other increased symptoms seen compared to bus mechanics. This task was also associated with a small but statistically significant decrease in airflow rate (FEV1/FVC%, $p < 0.05$).
4. Tungsten carbide grinding (particularly when coolant was used at least 50% of the time), was associated with significant reductions in average lung volumes (FEV1 and FVC) and with FEV1 reduced to the clinically abnormal range (all $p < 0.05$). Duration of work in jobs in which tungsten carbide grinding (wet or dry) was performed was also marginally significant as an additional predictor of reduced FVC ($p = 0.08$). No specific increases in respiratory symptoms were found in association with this task.
5. Once these job tasks were taken into account (as well as other predictors such as smoking and age), no additional differences were seen in health outcomes among the eight mills studied.
6. There were no significant relationships found between the change in lung function over one work shift and any of the daily metal exposure measurements. There was no evidence seen to suggest the presence of current cases of specific cobalt or chromium asthma.

Conclusions

1. The results of the respiratory health assessment provide evidence that the saw filers studied are at risk for work-related increases in acute respiratory and nasal symptoms as well as for measurable reductions in lung function.

The results support the hypothesis that chromium exposure from stellite welding may be leading to airway irritation, although they do not rule out the possibility that other welding fume exposures may be playing a role in the airway irritation found.

The results also provide strong support for the hypothesis that cobalt exposure from tungsten carbide grinding may be leading to significant reductions in lung volume, including levels in the clinically abnormal range. As lung volume reductions are the expected finding in hard metal lung disease, this result must be interpreted as indicating significant potential risk for this outcome in the saw filing work force.

2. It is somewhat reassuring that we did not find any obvious current cases of either hard metal lung disease or specific asthma. However, it would have been extremely unlikely to find such cases in a study of this size among currently employed tradesmen. This cross-sectional study does not allow us to determine conclusively whether or not the significant lung volume reductions found are indicative of the early stages of hard metal lung disease; however, given the poor prognosis for hard metal lung disease in some cases, the findings suggest the need for further follow-up of these and other saw filers in order to answer this question.
3. Exposure-response evaluation suggested that exposure to airborne cobalt at the proposed B.C. Permissible Concentration (0.020 mg/m^3) may be sufficient to lead to lung volume reductions in the clinically abnormal range; however, as this conclusion depends on an assumption that the exposure levels measured during the study reflect past exposure levels in these mills, this conclusion should be interpreted with some caution.

Recommendations: Industrial Hygiene Assessment

Follow-up by mill personnel

1. At wet tungsten carbide grinding machines and knife grinding machines which are currently not ventilated, enclosing or ventilating the machines should be considered. For tungsten carbide wet grinding machines, an alternate or additional control measure might be frequent changing of the coolant to minimize cobalt concentrations in the coolant. The change schedule required is currently unknown (see Recommendation 8. below, and Epilogue section 7.1 in the main body of the report).
2. Ventilation at tungsten carbide grinding machines, stellite heating operations, and babbitt areas that was rated "poor" should be considered for upgrading. Moving the exhaust hoods closer to the point of contaminant generation, more completely enclosing the operation (e.g., putting side walls down from canopy hoods), and ensuring that all contaminant generating operations are enclosed (e.g., hoods over babbitt pouring area as well as babbitt pot) would usually be effective and inexpensive means of improvement for the problems observed in the study mills. The success of these modifications can be tested with smoke tubes to visualize the draw of the hoods.
3. Consideration should be given to annual monitoring of personal exposures to cobalt in air for employees doing the following jobs:
 - grinding tungsten carbide tips at a wet grinder
 - grinding tungsten carbide tips at a dry grinder
 - heating stellite
4. Consideration should be given to annual monitoring of personal exposures to chromium in air for employees
 - working as knife grinders
 - doing stellite heating (i.e., in most cases, welding)
5. Consideration should be given to two metal substitutions:
 - changing to lead-free babbitt
 - changing to cadmium-free silver solder

If your mill chooses to make these substitutions, it is important to make sure that the potential harmful effects of metals in the new compounds are examined. Any components of concern in the new compounds should be monitored from time to time to make sure a new hazard is not introduced.
6. If your mill chooses to continue using lead babbitt, consideration should be given to implementing a blood-

lead monitoring program for employees using the babbitt (e.g., jobs which involve making babbitt guides, or weighting knives with babbitt). Air sampling is usually not considered an adequate way to check lead exposures. Family physicians can arrange to have blood lead levels checked. Blood lead samples can also be arranged through the Occupational Health Department of the Workers' Compensation Board.

7. Consideration should be given to annual monitoring of personal exposures to cadmium (if cadmium-containing silver solder is still used) and silver in air for employees using silver solder.

Future studies in these mills or in other saw filing rooms

8. This study was unable to determine how quickly high levels of cobalt accumulate in tungsten carbide grinding machine coolants, therefore no schedule for fluid replacement can be proposed. We therefore recommend that a study be done to determine the optimum time for replacing the coolant at tungsten carbide wet grinding machines to prevent the build up of cobalt in the fluid. Such a study would involve an initial complete replacement of the fluid in a series of wet grinding machines, then sampling over time to determine the rate of increase in cobalt concentrations. The study could also investigate whether removing solids from used coolant would be an effective means to maintain low cobalt concentrations, and determine what level of cobalt in coolant is required to minimize cobalt concentrations in air around wet grinding machines.

[Note that some coolant manufacturers have been trying to produce a fluid which will not leach cobalt from tungsten carbide. Evidence from studies to date at the University of Washington have not shown a benefit.]

9. The method by which cobalt and chromium were measured in this study did not indicate whether the metals were present in their simple metallic forms or in an ionized form. Since the form of the metal may influence disease processes, it would be useful to know which forms are present in the work room air. A follow-up study of saw filing room jobs with the highest potential for cobalt or chromium exposure, using different methods of exposure sampling and analysis, would identify what form(s) of metal exposures these individuals have.

Recommendations: Respiratory Health Assessment

Immediate follow-up of the current study group

1. We recommend that all participants in this study be evaluated with more detailed clinical tests, with the following order of priority:
 - chest xray testing on all participants

This should be performed on all participants in order to have sufficient comparative information on those who may have lung function abnormalities and those who do not.

This test will assist in the evaluation of possible hard metal lung disease.
 - complete lung function testing (diffusing capacity and subdivisions of lung volume) and CT scan for any participant with evidence of lung function abnormality or xray suggestive of hard metal disease

These tests are necessary to rule out (or confirm) a diagnosis of hard metal pneumoconiosis.

Future study of this group and others with similar exposures

2. We recommend that a follow-up study of respiratory health and exposure factors among saw filers be conducted in approximately one to two years time. This is necessary in order to provide confirmatory (or contrary) evidence for the results of this study. The follow-up study should include respiratory symptom assessment, lung function testing, chest xray, and blood testing, and should include the following components:
 - locating and testing retired saw filers (and saw filers who have left the trade, as feasible) to determine whether cases of hard metal pneumoconiosis are present;
 - repeated respiratory health testing of all saw filers who participated in this study to evaluate change in health status;
 - enrollment of saw filers from additional B.C. sawmills and other locations where saw filing occurs (selected at random); and
 - blood testing for evaluation of specific cobalt associated lymphocyte transformation on all participants to allow for the evaluation of whether or not the early respiratory effects of cobalt exposure can be tested by a blood test in the same manner as currently performed for beryllium exposure.

Recommendation: Exposure Standard for Cobalt

The average cobalt exposures of individual saw filers measured over the four test days of this study were all below both the current B.C. allowable exposure level of 0.10 mg/m^3 and the ACGIH TLV of 0.05 mg/m^3 , yet statistically significant reductions in lung volume were found in tungsten carbide wet grinders. The evidence from this study supports the proposal that the current exposure standards should be lowered. Based on our exposure-response evaluation, and using a cautious approach, we suggest that a time-weighted-average Permissible Concentration of 0.005 mg/m^3 may be appropriate.