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Prevalence of Chronic Pulmonary Disease in Aluminum Potroom Workers

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Employees of the aluminum reduction industry are exposed to a variety of potroom fumes, gases, and vapors; however, of primary concern from the standpoint of chronic lung disease are fluorides, in the form of hydrogen fluoride and particulate fluoride. Although hydrogen fluoride, fluorides, or other potroom inhalants have been alleged to produce chronic pulmonary disease — such as asthma,[1-4] emphysema,[1 2 5] chronic bronchitis,[2 4 6] or interstitial fibrosis[1 5 7 8] — the evidence is not impressive. None of these studies utilized a standardized respiratory questionnaire or spirometry to classify potroom workers in terms of a pattern of symptoms and flow-volume abnormalities; nor did any compile prevalence rates for various potroom dose groups so as to compare with appropriate control groups. The only epidemiologic study of potroom workers with spirometry measurements was by Kaltreider *et al.*,[9] where mean vital capacity was reported to be equal in potroom workers and controls; however, the design of this study was deficient from the standpoint of defining study groups and controls, and it did not rule out several selection factors. The vital capacity measurements were not adequate for determining chronic pulmonary disease prevalence, and the analysis of the data was inadequate to explore dose relationships or interaction of smoking habit.

The purpose of our research study was to determine the prevalence of chronic pulmonary disease among current and former potroom workers employed in the aluminum industry and to compare the findings with an appropriate control group. Specifically, the study group and control group samples were to be selected so as to detect at a high level of probability a two-fold increase in prevalence of chronic pulmonary disease, if such an increase existed among the aluminum plants compared to a sample of control workers with no known injurious agents associated with their current occupation. Chronic pulmonary disease was to be determined primarily by means of appropriate findings obtained from the combination of two tests: the standardized respiratory symptoms questionnaire, and forced expiratory spirometry. Additional prevalence data on sputum cytology, chest x-ray, closing volume measurement, $\alpha_1$antitrypsin, and blood and urine fluoride are published elsewhere.[10 11]

Methods

Selection of Study and Control Subjects. — Aluminum workers included in the study were male potroom workers and former potroom workers who, during the one year prior to November 1, 1973, were in the employ at either of two plants using a Prebake process or one plant using the Soderberg process. All workers recruited into the study group were further

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Table 1. — Smoking Categories.

Category	Definition
1	Never smoked, or total lifetime consumption has been less than 12 cigars, 12 pipefuls, or 400 cigarettes.
2	All exclusively current and former cigar and/or pipe smokers, regardless of quantity, and current or former cigarette smokers with a total consumption of less than ten pack years.*
3	Former cigarette smokers who have smoked equal to or more than ten pack years, but less than 39 pack years.
4	Former cigarette smokers who have smoked equal to or more than 39 pack years.
5	Current cigarette smokers who have smoked equal to or more than ten pack years, but less than 39 pack years.
6	Current cigarette smokers who have smoked equal to or more than 39 pack years.

Note: For individuals who smoked combinations of cigarettes, cigars, and/or pipes, the category designation was based on cigarette consumption.

* One pack year is one package (20 cigarettes) per day for one year, or a variant thereof with the same total (e.g., two packages per day for six months).

subcategorized by age, smoking history, and exposure history. Workers assigned in the potroom during the year prior to November 1, 1973, were subdivided into new hires, hired during the year and accumulating less than 500 hours in the potroom. All new hires from the Soderberg plant and the two Prebake plants were eligible for the study group; also eligible were all former and current potroom workers from the Soderberg plant plus a 25% random sample of former and current potroom workers from the rosters of the two Prebake plants. Each potroom worker was assigned an exposure score based on the number of hours of his exposure in the potroom and the estimated exposure level based on his job assignments obtained from personnel records and reviewed with him upon interview.

Control workers were matched to the aluminum workers, by age, within two years, and smoking history, within the same category. See Table 1 for smoking categories used in this study. One control worker was matched for each two aluminum workers. The controls were obtained from two populations,

Table 2. — Study Group and Control Group by Age Strata and Smoking Category.

Smoking Category	Age Strata (years) ≤ 35	36-50	≥ 51	Total (all Ages)
1	10.3%/15.0%*	2.4%/2.6%	1.5%/1.3%	14.3%/18.9%
2	27.2%/24.2%	3.7%/3.5%	3.1%/2.6%	34.0%/30.4%
3 or 4	3.1%/3.1%	4.8%/6.2%	9.0%/9.7%	16.9%/18.9%
5 or 6	18.6%/14.5%	11.2%/12.3%	5.0%/4.9%	34.9%/31.7%
Total	59.2%/56.8%	22.2%/24.7%	18.6%18.5%	100%/100%

* The entry 10.3%/15.0% means that 47 of 457 (10.3%) Study Group workers and 34 of 228 (15.0%) Control Group workers were less than 36 years of age and were in smoking category 1.

namely, shop personnel and other manual workers in the physical plant department of a university, plus linemen and equipment operators from a telephone company. The first step in recruitment was the administration of smoking histories to controls selected on the basis of age obtained from personnel records. An invitation for testing was extended to all controls from each of six decade age rosters, limits being placed on each age roster to correspond to the age distribution of the study group.

For both the study group and control group an effort was made to obtain satisfactory tests on all subjects in the group. Analysis of results was obtained on 183 Soderberg workers and 91 matched controls, 274 Prebake workers and 137 matched controls. The 183 represented 69% of 267 Soderberg workers included in the study, the 274 represented 82% of all 333 Prebake workers, and the 228 (91 + 137) represented 48% of all 476 in the control group. The nonresponse rates for the two groups were 29% and 14%, respectively, when adjusted for workers determined to be ineligible upon interview, and 20% for the control group when adjusted for those excluded from a match with a pair of study group workers. Exact age-smoking matches were effected in over 90% of cases; Table 2 shows that study group and control group compared favorably in smoking history and age. Age, weight, height, years of education, and racial distribution were all very similar also. Past work history was included in the analysis since more control subjects com-

Table 3. — Exposure Level Assignments.

Exposure Level	Job Title or Occupation: Prebake Process (ALCOA, Vancouver and ALCOA, Wenatchee)	Soderberg Process (Kaiser, Tacoma)
High	Anode changer, carbon changer, tapper-carbon changer, sweeper operator, craneman with controls, spare man, laborer, and siphon cleaner.	Pot operator, utility man, spare man, anode tender, sweeper operator, and paste tender.
Medium	Pot operator, potman, mechanized cell operator, craneman without controls, pot tender, potroom helper, potroom trainee, pot liner, pot repairer, burner, pot lifter, digging machine operator, pot rebuilder, tapper, and siphoner.	Siphoner, crane operator, mobile equipment operator (MEO), pot rebuilder, pot rebuilder MEO, and supervisor.
Low	Foreman leadman, service man, tool-room personnel, air control personnel, technicians, control, process control checker, maintenance man, welder, electrician, and craftsman.	Service man.

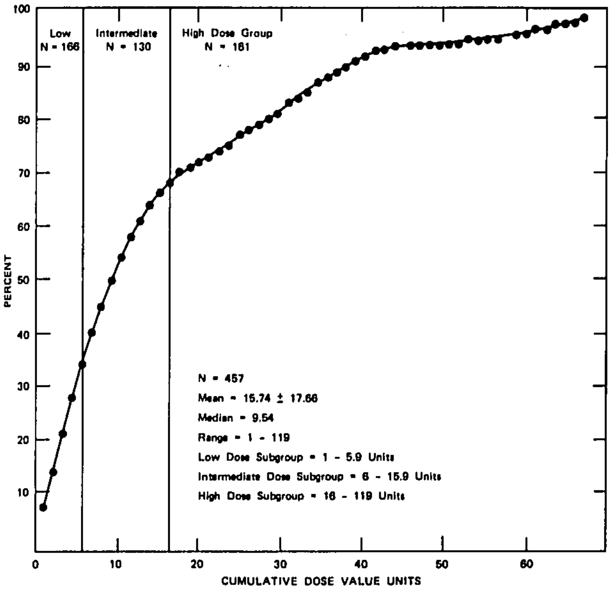


Fig 1. — Cumulative percentage distribution of study group dose values.

pared with study subjects (27% vs. 17%) reported past exposures to asbestos or beryllium or a history of work in mining, quarrying, foundry, pottery, or a cotton flax or hemp mill. Other less specific occupational history information, e.g., exposure to chronic acid mist, fiberglass, and epoxy, also showed this trend toward more exposures in controls.

Exposure in potrooms was graded as high, medium, and low for each of the two processes using job titles. These are indicated in Table 3. Arbitrary numerical values were assigned: 3 for each full year at a high exposure job, 2 for each year at a medium exposure job, 1 for each year at a low exposure job, and 0 for each year at a job having no potroom exposure. Cumulative dose values for the 457 study subjects are displayed as a cumulative percentage distribution in Figure 1.

Table 4. — Criteria Used in Establishing Major and Minor Respiratory Disease Symptomatology Categories.

Major Symptomatology Category

- Morning cough 50 or more days during the past year and a duration of more than one year.
- Sputum production (in the morning or later in the day) on 50 or more days during the past year.
- More than one period of increased cough and sputum lasting for three weeks or more during the past three years.
- Wheezing or nonexertional attacks of dyspnea occurring 50 or more times during the past year.
- Dyspnea while walking on level ground with person of own age or while walking on level ground at own pace.

Minor Symptomatology Category

- Morning cough either less than 50 days during the past year or of a duration of one year or less.
- Sputum production (in the morning or later in the day) less than 50 days during the past year.
- One period of increased cough and sputum lasting for three weeks or more during the past year.
- Wheezing or nonexertional attacks of dyspnea occurring less than 50 times during the past year.
- Dyspnea while hurrying on level ground or walking up slight hill, but not while walking on level ground with person of own age or at own pace.

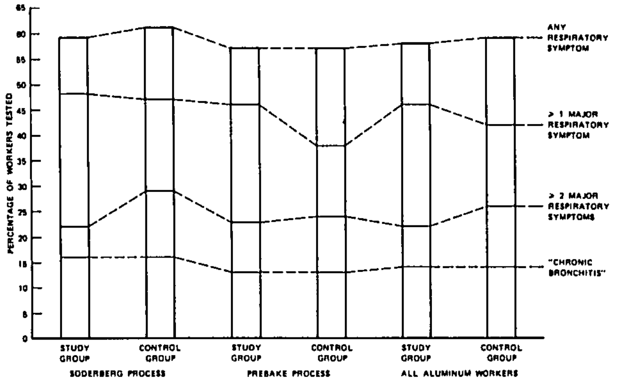


Fig 2. — Respiratory symptom categories by group: Soderberg, Prebake and all aluminum.

Dose subgroups: Low, Intermediate, and High Dose are indicated in the figure. The Prebake group had a higher mean dose compared with the Soderberg group (18.4 vs. 11.8).

Testing Procedures. — Field testing was undertaken in two mobile laboratory trailers. The smaller trailer was used to meet subjects, obtain height, weight, and blood pressure, and administer the questionnaire. The second trailer was used for electronic spirometry and other tests not reported upon herein (closing volume, chest x-ray, sputum collection for cytology, and venous blood collection for $\alpha_1$antitrypsin analyses).

The questionnaire, in addition to questions on occupational exposure, included standard questions on respiratory symptoms[12] in order to ascertain the frequency and severity of cough, phlegm, wheeze, and dyspnea. Table 4 shows the five types of major respiratory symptoms and the five minor symptoms used in this study. The combination of major cough and major phlegm was classed as "chronic bronchitis."

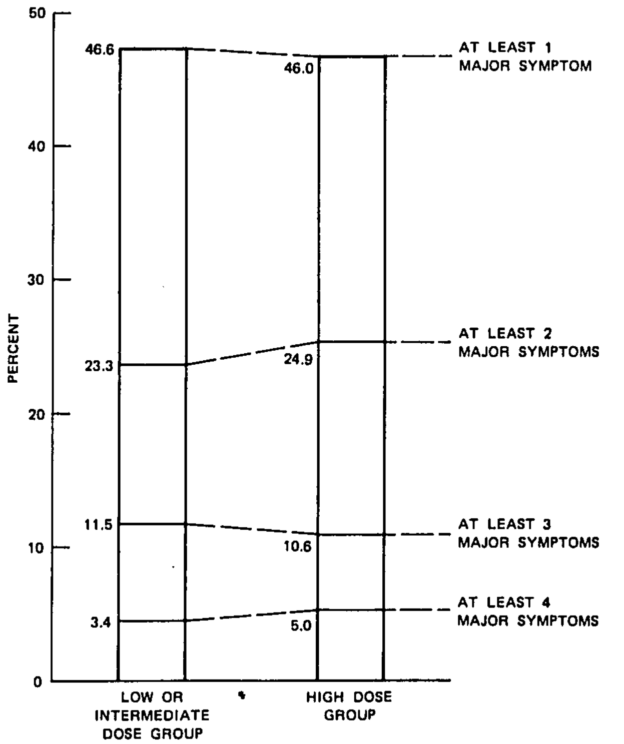


Fig 3. — Percentage frequency of major symptoms for high dose group compared with the remainder of the study group.

The volume signal from the Ohio 840 spirometer was recorded on a Beckman DRS 1000 digicorder. Five trials of maximal forced expiration were attempted by each subject, and the technician attempted to obtain reliable results by comparing successive trials on a storage oscilloscope using the flow-volume loop. The spirometry data to be included in this report are the forced expiratory volume in one second (FEV_1) and the total volume (FVC). The spirometry tapes were evaluated by a computer program that assembled 55 spirometric measurements for each trial, selected the best trial, gave an interpretation category for FEV_1 and FVC (normal, borderline, and abnormal for each on the best trial), and assigned a reliability code in order to identify and eliminate unsatisfactory tests. Extensive methods for calibration and data handling were developed. A deviation of not more than 1.645 units below predicted or any value above predicted were considered to be within normal limits. A deviation of 1.646 to 2.326 units below predicted was classified as borderline; a deviation of more than 2.326 units below predicted was considered abnormal. Predicted values based upon age and height were determined for FEV_1 and FVC using regression formulas previously published.[13] For each subject a best trial value for FEV_1 and for FVC in liters and in deviation units from predicted were calculated and a designation was made of abnormal spirometry category. There were eight abnormal categories:

Category	FEV_1	FVC
1	borderline	normal
2	abnormal	normal
3	abnormal	borderline
4	borderline	borderline
5	normal	borderline
6	abnormal	abnormal
7	borderline	abnormal
8	normal	abnormal

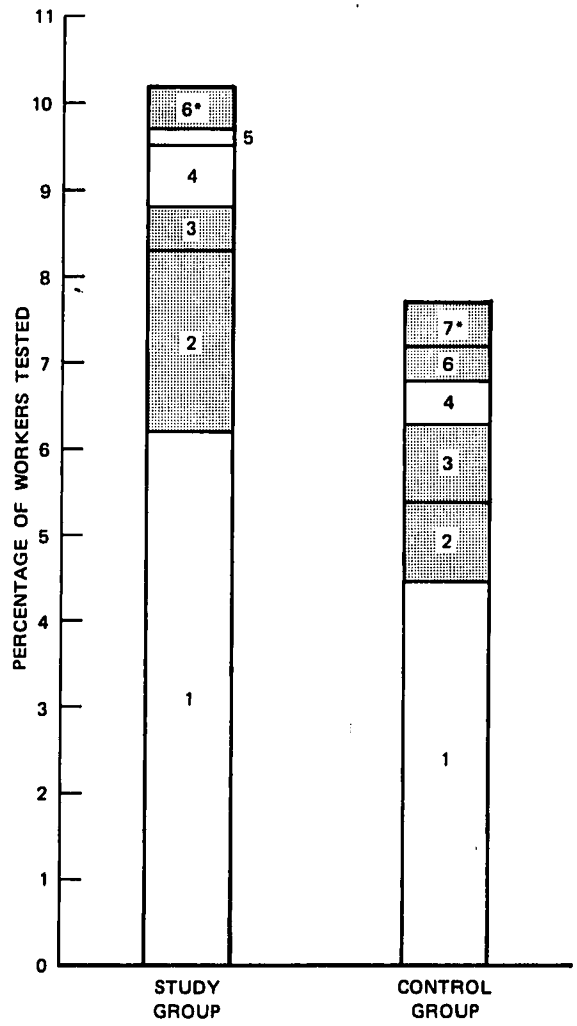
The combination of one or more major symptoms and any of the above eight abnormal spirometry categories was used as the principal observation indicating chronic pulmonary disease.

Results

The prevalence of respiratory symptoms did not differ between the study group and the control group. Figure 2 shows the comparisons of prevalence rates for the study group versus the control group by plant process. The prevalence rates were examined using four cutoffs: (1) workers with major cough and major phlegm ("chronic bronchitis"), (2) with two or more major symptoms, (3) with one or more major symptoms, and (4) with one or more major or minor symptoms. The principal cutoff used in our definition of CRD prevalence was (3); this prevalence rate was examined in detail for significant differences among workers in three exposure dose subgroups and the three worker classification subgroups.

The ratio of prevalence rates for the intermediate dose group was 46.2%/41.5%, or 1.11, very similar to the values for the entire study group compared to the entire control group. The specific rates for a given study subgroup cannot be compared with another study subgroup because the age and smoking characteristics are different. The ratio comparisons between study and control groups shown in Table 5 are not statistically significant, and no consistent trend is apparent, such as significantly larger ratios for high exposure groups or former potroom workers. The high exposure group was also compared with the remainder of the study group, controlling for age and smoking history and using successive cutoffs of 1, 2, 3, and 4 or more major symptoms. No differences were observed, as shown in Figure 3.

The prevalence of abnormal spirometry was examined using two ventilatory parameters (FEV_1 and FVC) and two cutoffs (<1% or 2.326 deviation units and < 5% or 1.645 deviation units). The prevalence for the eight possible combinations of these spirometry abnormalities is shown in Figure 4. No significant differences were observed between the study group and the control group. (The frequency of either the FEV_1 or the FVC being below the 1% cutoff is demarcated in Figure 4.) The prevalence ratio, using as the basis that either parameter or both were below the 5% cutoff, was 1.28 for the entire study group compared with the matched control; moreover, the ratios



*Coded as follows:

		FVC		
		NORMAL	1% TO 5%	<1%
FEV_1	NORMAL	–	5	8
	1% TO 5%	1	4	7
	<1%	2	3	6

Fig 4. — Abnormal spirometry categories by group: all aluminum workers.

Table 5. — Frequency of One or More Major Respiratory Symptoms for Dose and Worker Classification Subgroups.								
		Exposure Level			Worker Classification			
	Total Groups	Low Dose Group	Intermediate Dose Group	High Dose Group	Current	Former	New Hire	
Study Group (SG)	212/457 (46.4%)	81/166 (48.8%)	60/130 (46.2%)	71/161 (44.1%)	169/308 (54.9%)	25/64 (39.1%)	18/85 (21.2%)	
Control Group (CG)	95/228 (41.7%)	31/83 (37.3%)	27/65 (41.5%)	37/81 (45.7%)	79/154 (51.3%)	10/32 (31.3%)	6/43 (14.0%)	
Ratio (SG/CG)	1.11	1.31	1.11	0.96	1.07	1.25	1.51	

were 1.26 and 1.34 for the Soderberg process and Prebake process groups, respectively. The ratios for FEV_1 below the 5% cutoff were also studied for the three dose groups by process group, and the ratios were near unity for all groups except for the high dose group where it was 1.47 for the Soderberg group and 1.54 for the Prebake group. None of these ratios was significant. The effect of exposure level and worker classification was also examined by making t-test comparisons for means of absolute liter values and deviation units for various subgroups.

In Table 6 both liter differences and deviation unit differences between study group and matched control groups, and their subgroups for exposure level and worker category, are compared. The deviation unit values for FEV_1 and FVC are plotted in Figure 5. For the entire study and control groups, the FVC and deviation FVC differences were statistically significant; the study group values were significantly *larger* for the study group. No statistical significance was found for FEV_1 differences except for the former potroom workers who had *lower* mean deviation values compared with their matched controls. This same subgroup comparison showed no significant mean difference in FVC deviation units (i.e., the mean value for study group former potroom workers was 0.337 units above predicted values, whereas the mean value for their age-smoking matched controls was 0.348 units above predicted values, controlling for age and height). For both current and new hire groups, the deviation FVC values were statistically significant in favor of the potroom workers. The trend is for higher exposure level subgroups to have a relatively *higher* FVC compared with lower dose groups when controlling for smoking, as shown in Figure 5; however, this trend was not statistically significant. In summary, the only observations suggesting a significant effect of potroom exposures is in mean FEV_1 among former potroom workers; however, the inconsistency of this FEV_1 finding when compared by exposure dose places this effect in doubt. Moreover, the lack of a significant difference in the prevalence of abnormal FEV_1 values using either the 5% or the 1% cutoffs also supports this contention of a no exposure effect.

The combination of one or more major symptoms and abnormal spirometry (below the 5% cutoff) was used as the

Table 6. — Spirometry Measurements by Dose and Worker Classification Subgroups. (Milliliters Mean Value + Standard Error)

Group	FEV1.0 Measured	FEV1.0 Deviation from Predicted*	FVC Measured	FVC Deviation from Predicted*
Study group	4053 ± 42.5	−0.099 ± 0.061	5215 ± 45.0	+0.415 ± 0.052
Control group	4053 ± 53.6	+0.003 ± 0.075	5044 ± 59.6	+0.242 ± 0.063
Low dose				
Study group	4453 ± 56.6	+0.184 ± 0.080	5601 + 69.0	+0.577 ± 0.088
Control group	4390 ± 55.7	+0.222 ± 0.084	5407 ± 65.4	+0.452 ± 0.073
Intermediate dose				
Study group	4080 ± 79.2	−0.155 ± 0.119	5210 ± 76.4	+0.386 ± 0.095
Control group	4123 ± 67.2	+0.050 ± 0.098	5080 ± 77.6	+0.220 ± 0.083
High dose				
Study group	3617 ± 69.7	−0.346 ± 0.106	4824 ± 75.0	+0.272 ± 0.087
Control group	3645 ± 59.4	−0.264 ± 0.091	4635 ± 62.8	+0.040 ± 0.071
Current				
Study group	4002 ± 47.5	0.109 ± 0.070	5161 ± 50.6	+0.386 ± 0.059
Control group	4011 ± 43.8	0.044 ± 0.063	5000 ± 48.5	+0.200 ± 0.051
Former				
Study group	3987 ± 129.5	−0.289 ± 0.170	5119 ± 115.9	+0.337 ± 0.130
Control group	3986 ± 93.3	+0.060 ± 0.126	5007 ± 104.4	+0.348 ± 0.108
New Hire				
Study group	4606 ± 99.1	+0.290 ± 0.162	5846 ± 145.3	+0.787 ± 0.185
Control group	4530 ± 98.0	+0.327 ± 0.151	5488 ± 123.1	+0.443 ± 0.141

*Minus sign designates below predicted, and plus sign designates above predicted values.

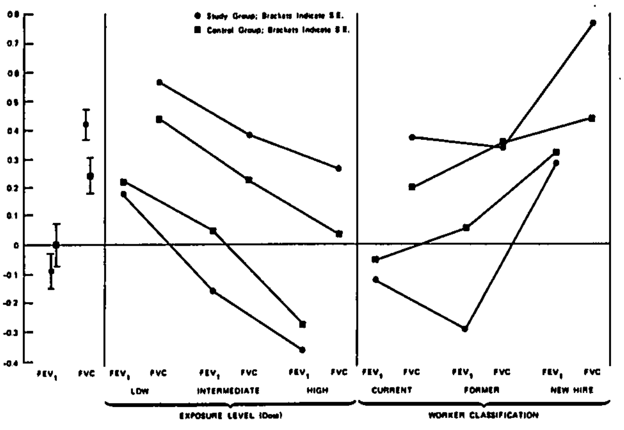


Fig 5. — Mean deviations from predicted spirometry values for dose and worker classification subgroups.

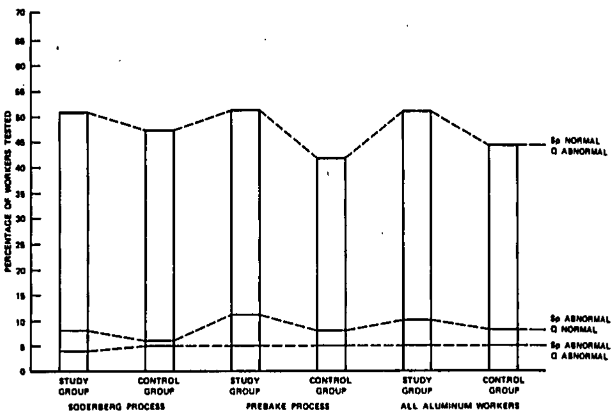


Fig 6. — Questionnaire symptoms, Q, and/or spirometry, Sp, by group: Soderberg, Prebake and all aluminum.

definition of chronic respiratory disease (CRD). Figure 6 shows no significant difference in comparing the prevalence of CRD in potroom workers (4.9%) versus the controls (5.3%), or in the Soderberg (3.8% vs. 5.5%) and Prebake (5.5% vs. 5.1%) processes. The prevalence comparisons of abnormal spirometry and normal questionnaire, and the converse, also showed no significant differences between the study group and the control group. These prevalences are shown in Figure 6; also given are the percent prevalences by plant process.

Since more controls than study subjects reportedly had former occupations with significant exposures to respiratory disease agents, the analysis was extended to control for such reported past occupational exposures (asbestos, beryllium, mining, etc.). The occurrence of past exposure would not be expected to occur equally across all age and smoking history groups, thus the analysis of those with and without such past occupational exposures required adjusting rates to the age and smoking characteristics of the total study and control group. The study group and control group were examined separately; however, the overall prevalence rate for persons with past exposures was 5%, whereas the prevalence for those without such exposures was 5.2%, thus indicating no major effect of the past history questions on this study. This analysis was also extended to include less specific questions of past exposures (such as "any dusty trade"), and the analysis again showed no significant interaction of past occupational exposures.

Discussion

The principal question addressed by this industrial prevalence study can be stated as follows: Does work in the potroom lead to a doubling of the prevalence of chronic obstructive lung disease? Several key reservations were inherent in our analysis of this question, and each can be discussed in detail:

1. Does our population of current and former aluminum potroom workers in three plants remain in the plant work force such that the aluminum plant roster is representative of all occupational risk groups? A corollary is: Do workers with early disease leave the work force?

2. Does our cross-sectional randomized and stratified sample of a risk population, consisting of 457 potroom (183 Soderberg and 274 Prebake process) workers (308 current, 64 former, and 85 new hires), represent that population so as to estimate expected prevalence rates to detect a true two-fold greater prevalence in the population at risk? A corollary is: Does the sample represent a reasonable allocation of exposure doses such that the response can be applied across dose subgroups?

3. Does a control population for aluminum workers exist such that all important extraneous sources of disease risk are comparable to the aluminum study population? A corollary is: Does our matched group of 228 university physical plant employees and telephone workers correspond reasonably well to the risk group so that potroom exposure is the principal difference?

4. Does our methodology for identifying persons with chronic obstructive lung disease have such reliability and validity that one can be confident of numerator events? A corollary is: Are our measurements clinically meaningful?

Each of these basic epidemiologic questions for this industrial prevalence study expands into a series of subsidiary questions and could generate a set of contrasting questions for alternative studies, such as longitudinal morbidity and mortality studies.

Returning to the four key reservations, the results should be viewed with the following cautions:

1. No retired, terminated, or otherwise separated employees who were former potroom workers were included in this study. The former potroom workers were in actuality a subgroup of those still employed by the aluminum industry! Moreover, our roster was a current one, so that active employment (and perhaps its corresponding health selection bias) was an implicit requirement for participation. Fortunately, the numerator condition we were studying is not disabling until many years have elapsed. However, if acute irritation is particularly objectionable to a new worker, this particular job may not be acceptable, and the new hire may seek transfer or quit. Moreover, if this irritancy tendency is correlated with chronic disease susceptibility, a survivor group may be resistant; for example, no workers with $\alpha_1$antitrypsin deficiency would remain if this were a risk factor that is associated with both serious and obvious acute effects, such as susceptibility to "potroom asthma." A small study of potroom employee turnover was performed. Of the 308 current potroom workers on November 1, 1972, 8.4% were no longer in the potrooms one year later; and for 85 new hires on the same date, 36.0% were no longer in the potrooms one year later. Over 75% of this turnover was in the group under 36 years of age. It was judged to be questionable

that we could very effectively identify from our cross-sectional data whether self-selection factors related to future chronic respiratory disease were operating in this turnover among young potroom workers.

2. The sample size was calculated to optimize estimates of prevalence of chronic respiratory disease among current, former, and new hire potroom workers in the two processes. A sample of 457 study group aluminum employees matched to 228 control group workers was shown to be sufficient to detect a study group prevalence of 10% of chronic respiratory disease (46/457) and recognize a significant difference at the 5% level (α error), assuming a prevalence of 5% in the age-smoking history matched control group (12/228). The power of this sampling design was 80% (β error = 20%). Stratified random sampling was performed from a composite three-plant roster using a sampling fraction of 100% for one low risk group, namely new hires. (If a 25% sample had been used for this group, perhaps only about 25 such persons, rather than 85, would have been studied, and far fewer inferences could have been made concerning the group.) This new hire subgroup serves to provide a low dose internal control. The second decision to allocate the sample was related to the two processes, wherein current potroom workers in the Soderberg process were assigned a 100% sampling fraction rather than 25%; this increased the yield of this group to 130 persons rather than 50 current potroom workers in the Soderberg process and markedly improved our ability to compare processes. The sample of the two groups, study group and control group, was of borderline quality from the standpoint of response rate. This was especially the case for the Soderberg process subgroup, wherein the nonresponse rate was 29%. A special study of the Soderberg plant medical records of the nonrespondents was performed, and the frequency of abnormalities documented in those records was found to be comparable to the respondent group. The frequency of abnormal spirometry at the 5% cutoff was 4% for the nonrespondent group, about the same for respondents of a similar age distribution. The frequency of hospitalizations during the past ten years for respiratory disease was 2% for the nonrespondent group. About 10% of them had a diagnosis of chronic respiratory disease, 36% were moderate or heavy smokers, 20% turnover occurred, the ratio of current to former to new hires was 7:2:1, and the ratio of the three age groups ($\leq$35, 36-50, $\geq$51 years) was 7:2:1 — all of this being data consistent with the contention that the respondents and nonrespondents at this plant do not differ in relevant characteristics.

3. A control group of similar age, smoking history, family history for chronic obstructive lung disease, childhood respiratory infection rates, and so on, would be ideal to compare the prevalence in the study group to a control group. In our study, matching was only performed for age and smoking, and some other factors were examined for comparability after the matching was completed. It should be noted that only minor differences were observed in education, size, blood pressure, and the like; moreover, it was our judgment that inferences drawn from comparisons of matched groups do not suffer from an imbalance of any known extraneous sources of chronic respiratory disease risk. One exception to this was past occupational exposure which required a separate analysis because more controls reported such exposures compared with potroom workers. The study group prevalence ratio was also examined in dose subgroups. There were three approximately equal groups: high, intermediate, and low. Another key internal comparison was the prevalence among the former potroom subgroup compared to its matched control; former potroom workers may be a key subgroup since they may no longer be in the potroom because of effects of long exposure. In this manner the study design included the elements of external controls (dose and worker subgroups), as well as the comparison of the two process groups.

4. The reliability and validity of the questionnaire and spirometry for detecting chronic respiratory disease has been well established by numerous epidemiologic studies, although the clinical application of these data to individual patients is controversial because the impact of this as a form of disease detection is dubious from the standpoint of reversing the disease process by any known therapeutic means. In general, the clinical problem is that *early* chronic obstructive lung disease cannot be detected by questionnaire and spirometry; and clearly established disease patterns for epidemiologic purposes usually require combined test results, such as defined in this study. The validity of the test cannot be asserted for closing volume or radiographic interpretation. No clear cutoffs for the closing volume test can be stated that are indicative of "small airway disease" or any other chronic obstructive lung disease. Likewise, radiographic criteria for "obstructive emphysema" have been considered unacceptable except as crude epidemiologic indicators. For example, a normal functional state is frequently observed in many young people with good quality chest radiographs interpreted by consensus as abnormal. The sensitivity of chest radiography has been observed to be low, especially for mixed chronic bronchitis and emphysema. In persons with radiographic abnormalities, such as hyperlucency, and abnormal closing volumes but normal spirometry and no respiratory symptoms, a wise clinical course might be to be vigilant for "small airway disease" as a prelude to emphysema; however, the hypothesis has not been tested and remains speculative. In a follow-up paper we will attempt to evaluate the sensitivity of other tests and compare the results reported herein with these other tests.

We continue to be impressed with the value of electronic spirometry parameter FEV_1 as an objective measurement to supplement the questionnaire. Abnormal or borderline FVC is unusual without an abnormal or borderline FEV_1, unless one is dealing with a group at risk of a restrictive disease, such as asbestosis. A borderline FEV_1 is the most common finding in an industrial prevalence study, aside from a normal test result; and this finding is more associated with wheeze and non-exertional dyspnea than with "chronic bronchitis" symptoms. It is our impression that the prevalence of "chronic bronchitis" continues to be largely associated with smoking history, especially as reflected in pack-years; whereas, nonsmokers with wheeze and nonexertional dyspnea on the job frequently show major FEV_1 decrements during the course of the work day. Early in employment decrements appear to be small and reversible, but protracted exposure may lead to irreversible FEV_1 decrements. Smokers with "chronic bronchitis" likewise appear to have FEV_1 decrements when exposure to occupational lung irritants, and in many cases the symptoms of such workers appear to be more protracted and include afternoon and evening cough and phlegm. That some new hires reportedly leave employment because of "intolerance" to potroom inhalants is not surprising;

moreover, the selection factors that may be operative undoubtedly could effectively remove any risk of chronic lung disease by leaving only the "more resistant" workers. Medical screening of potroom applicants may be beneficial in weeding out some susceptibles.

A prevalence study such as is reported herein is not inconsistent with the hypothesis that those who are hired and later leave because of "breathing problems in the potroom" would have developed chronic lung disease if they had stayed and "stuck it out." Such a hypothesis is difficult to test. Careful spirometry performed frequently during the first year of employment of a group of new hires would be a possible first step; an electronic spirometric FEV_1 would be a candidate parameter to follow in such a research design. Likewise, follow-up on persons selecting themselves out of potrooms would assist in resolving the issue, and longitudinal studies of potroom new hires with abnormal α_1 phenotypes would also be recommended. It is reassuring, however, that the prevalence of chronic lung disease among those current and former potroom workers who remain in the employ at three aluminum plants is not significantly increased. In future reports we will examine other spirometric parameters, such as terminal flow rates, and other tests to gain further understanding of early chronic lung disease, a worthy endeavor of preventive medicine.

Summary

A prevalence of chronic pulmonary disease, based upon interview and spirometry, was noted in 457 male aluminum potroom workers to be 4.9% and in the comparison group of 228 skilled laborers not currently exposed to similar occupational risks, 5.3%.

The results were analyzed by comparing the ratio of prevalence; for example, the overall ratio was 4.9%/5.3%, or 0.92. The ratios were examined for the sample of workers employed in the one plant using the Soderberg process and the workers in the two plants using the Prebake process. Likewise the ratios were compared for three subgroups based upon potroom exposure history, and three groups for current employment status (former potroom worker, new hire in the potroom, or current potroom worker in excess of a minimum tenure). In none of these did the ratios show any differences from unity.

Individual tests were examined in a similar manner, also using prevalence ratios. The questionnaire data on respiratory symptoms were examined using multiple levels of symptomatology, and the spirometry test was likewise analyzed in several different ways. The forced expiratory volume in one second and the total forced vital capacity were used for this analysis, and analysis of group and subgroup means and the prevalence ratios for multiple cutoffs did not show any significant differences.

In conclusion, this prevalence study failed to show any differences, using respiratory symptoms and two spirometric measurements. The limitations of the study have been discussed; however, in view of the results reported here, we conclude that potroom workers do not incur a major risk of chronic pulmonary disease.

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