

Respiratory Effects of Diesel Exhaust in Salt Miners¹

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Introduction

The diesel engine was invented by Rudolph Diesel in 1892. The first diesel engine locomotive used in an underground mine was in 1927 in the Ruhr coal mining district of Germany (1). Despite the current increase in the manufacture and use of diesel engines, the risk associated with exposure to diesel exhaust emissions in underground mines is not known (2). The advantage of studying the effect of diesel emissions on salt (NaCl) miners is the lack of any known effect of NaCl on the respiratory health parameters used in this study (3). The potential health risks from diesel exposure include irritation, especially complaints of odor and eye irritation (4, 5), nonmalignant respiratory disease, and lung cancer.

There have been several studies of the respiratory health of underground miners in dieselized mines. The ore being mined was coal (6), potash (7, 8), and iron ore (9, 10). These were all cross-sectional morbidity studies of respiratory health. No effects conclusively attributable to diesel emissions were noted.

The specific questions addressed in this cross-sectional study are: (1) Is there an increased prevalence of respiratory symptoms (cough, phlegm, dyspnea) associated with diesel exposure? (2) Is there an association of reduced pulmonary function and diesel exposure?

Methods

We surveyed 259 white male workers in 5 salt mines (labeled Mines A through E). Each worker was administered a British Medical Research Council Respiratory Questionnaire. Cough, phlegm, and dyspnea were the symptoms analyzed in this study. Workers were categorized as smokers, ex-smokers, and nonsmokers, and the number of pack-years was used as the quantitative measure of smoking.

Each worker performed a minimum of 5 forced expirations on an Ohio 800 rolling seal spirometer (Ohio Instruments Madi-

SUMMARY The respiratory health of 259 white males working at 5 salt (NaCl) mines was assessed by questionnaire, chest radiographs, and air and He-O₂ spirometry. Response variables were symptoms, pneumoconiosis, and spirometry. Predictor variables included age, height, smoking, mine, and tenure in diesel-exposed jobs. The purpose was to assess the association of response measures of respiratory health with exposure to diesel exhaust. There were only 2 cases of Grade 1 pneumoconiosis, so no further analysis was done. Comparisons within the study population showed a statistically significant dose-related association of phlegm and diesel exposure. There was a nonsignificant trend for cough and dyspnea, and no association with spirometry. Age- and smoking-adjusted rates of cough, phlegm, and dyspnea were 145, 159, and 93% of an external comparison population. Percent predicted flow rates showed statistically significant reductions, but the reductions were small and there were no dose-response relations. Percent predicted FEV₁ and FVC were about 96% of predicted.

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son, WI).² Maximal forced vital capacity (FVC) and forced expiratory volume in one second (FEV₁) were obtained from all workers. Peak expiratory flow rate (PEFR) and flows at 50 and 75% of FVC ($\dot{V}_{\max_{50}}$, $\dot{V}_{\max_{75}}$) from a maximal envelope curve were obtained from workers at Mines A, D, and E, but were not available from Mines B and C. Three spirometry tests were obtained in 189 subjects after the spirometry obtained during air breathing. The subject expired to residual volume (RV) and then did 3 inspiratory vital capacity (VC) maneuvers breathing the He-O₂ mixture before performing the forced expiration. Vital capacity had to agree within 5% to be accepted. The response to breathing He-O₂ was calculated as the percentage increase in breathing He-O₂ compared with breathing air at 50 ($\Delta\dot{V}_{\max_{50}}$) and 75% of FVC ($\Delta\dot{V}_{\max_{75}}$), i.e.,

$$\frac{\Delta\dot{V}_{\max_{50}}}{\dot{V}_{\max_{50\text{Air}}}} = \frac{[\dot{V}_{\max_{50\text{He-O}_2}} - \dot{V}_{\max_{50\text{Air}}}]}{\dot{V}_{\max_{50\text{Air}}}} \times 100.$$

Height was measured with the shoes on, and shoe heel height was subtracted from total height.

Chest radiographs of each worker were independently read by 3 "B" readers. Because there was only one case each of rounded and irregular opacities (Grade 1), no further analysis of pneumoconiosis was attempted.

Work histories of each worker were obtained by questionnaire and from personnel records. There were no diesels used at Mine C, and very limited use of diesel equipment at Mines A and B. Jobs at these 3 mines were therefore classified as nondiesel.

Mines D and E had extensive diesel use underground, and jobs in these mines were classified as diesel. Surface jobs at Mines D and E were classified as nondiesel as there were no diesel engines used aboveground. The exposure variable used in the analysis was years worked in diesel jobs.

Diesel tenure was used as a continuous variable in the internal analysis to test for statistical significance. For presentation of results, each worker was classified into a low (≤ 1 yr diesel tenure), medium (1 to 7 yr diesel tenure), or high (> 7 yr diesel tenure) diesel exposure category. Cumulative and average exposure to respirable particulate and NO₂ for these miners was estimated in a previous paper (11) and are presented for each exposure group to further characterize these categories.

To evaluate diesel exposure effects, two kinds of comparisons are presented. One is internal, comparing salt miners with high exposure with those with low exposure. The second is external, and after adjustment for age and smoking differences, compares the salt miners with a population of "blue collar" workers.

For the internal analysis of symptoms, a logistic model was used. The predictor variables were age, pack-years, and diesel ten-

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² Mention of brand names is for identification only and does not imply endorsement by NIOSH, CDC, USPHS, or DHHS.

TABLE 1
CHARACTERISTICS OF WHITE MALE SALT MINERS BY DIESEL
EXPOSURE CATEGORY

	Diesel Exposure Category		
	Low	Intermediate	High
n	127	65	67
Age, yr	36 (13)*	36 (11)	50 (8)
Total tenure, yr	8 (10)	7 (7)	20 (8)
Diesel tenure, %	2.2 (40.0)	75.5 (31.7)	89.9 (16.7)
Respirable Particulate			
cumulative, mg/m ³ × yr	34 (63)	36 (22)	204 (102)
Average	0.40 (0.32)	0.64 (0.30)	0.82 (0.26)
NO ₂			
Cumulative, ppm × yr	36 (76)	90 (71)	600 (420)
Average	0.64 (1.01)	1.77 (1.26)	2.21 (1.14)
Nonsmoker			
n	25	8	17
Age, yr	28 (11)	36 (10)	50 (10)
Total tenure, yr	3.6 (4.3)	4.9 (2.5)	20.7 (7.9)
Diesel tenure, %	15.4 (34.3)	84.7 (22.6)	88.4 (15.3)
Ex-smokers			
n	25	14	20
Age, yr	42 (15)	43 (15)	52 (7)
Total tenure, yr	11.1 (11.4)	12.0 (11.6)	21.5 (7.7)
Diesel tenure, %	13.6 (33.2)	62.9 (40.1)	90.8 (16.6)
Cigarettes/day	20 (12)	33 (19)	30 (20)
Pack-years	21 (28)	31 (40)	30 (23)
Smokers			
n	77	43	30
Age, yr	36 (12)	33 (8)	49 (9)
Total tenure, yr	7.8 (10.0)	5.2 (5.1)	19.2 (7.9)
Diesel tenure, %	27.3 (43.2)	77.9 (29.5)	90.2 (18.1)
Cigarettes/day	23 (13)	26 (12)	27 (14)
Pack-years	24 (21)	22 (17)	41 (23)

* Numbers in parentheses are standard deviations.

expected × 100) pulmonary function were then compared.

Results

The percentage of nonsmokers (19%), exsmokers (23%), and smokers (58%) in the study population was typical of a working population. The workers in the high exposure category were almost 15 yr older and had worked 12 to 13 yr longer in the salt mines than workers in the intermediate and low exposure groups. The estimated cumulative NO₂ and respirable particulate exposure was 5 to 12 times greater in the high exposure group than in the low exposure group (table 1).

Internal Comparison

About one quarter of the study population had cough and/or phlegm, and 7% had dyspnea. Pack-years was significantly associated with increased cough and phlegm, but not with dyspnea. All symptoms showed an increased observed/expected ratio in the high exposure groups, but the association was statistically significant only for phlegm (table 2).

Pulmonary function showed no association with diesel tenure. The association with age and height was as expected. Smoking was associated with reductions in air and He-O₂ spirometry (not significant for FVC) (table 3). Mine was significantly associated with differences in FVC, PEFR, and ΔV̇max₅₀. Residual pulmonary function by exposure category and adjusted for age, height, pack-years, and mine are presented in table 4. There was no pattern for high diesel exposure categories to show a reduction in pulmo-

ure in years. The results are presented as observed and expected values for the 3 diesel exposure categories. Statistical significances were based on logistic log likelihoods using the continuous exposure variable of diesel tenure and not the exposure categories. The association of pulmonary function with diesel exposure was analyzed by multiple regression techniques. Age, height, pack-years, mine, and diesel exposure were the predictor variables.

For the external comparisons, symptoms in the study population were compared with those in a population of North Carolina "blue collar" workers employed in industries with little or no exposure to known lung irritants. This population was studied by NIOSH as a control population for comparison with "exposed blue collar" populations. Symptom comparisons were made after indirect adjustments for age and smoking, and stratification by exposure category. Symptom rates in each 20-yr age group and smoking category of the control population were multiplied by the number of persons in the same age-smoking category of the salt miner population to get "expected" numbers of those with symptoms. The actual number of those in the salt miner population with symptoms was then compared with the "expected" number as an observed/expected ratio. The signifi-

cance of the differences is evaluated by 95% confidence intervals about the observed/expected ratios. For pulmonary function, predictive equations for each smoking category in the comparison population were used to derive a predicted pulmonary function value for each salt miner. Mean values of the age-, height-, and smoking-adjusted percent predicted (observed/

TABLE 2
OBSERVED AND EXPECTED PREVALENCE (%) OF SYMPTOMS BY DIESEL EXPOSURE
WITHIN THE STUDY POPULATION

	n	Observed (%)	Expected (%)	O/E	Comment
Cough*	259	24.3			
Low	127	18.1	22.8	79	p < 0.10 for diesel tenure; adjusted for age (p > 0.40) and pack-years (p < 0.0007).
Intermediate	65	23.1	23.6	98	
High	67	37.3	27.9	134	
Phlegm†	259	28.2			
Low	127	14.2	25.8	55	p < 0.0001 for diesel tenure; adjusted for age (p > 0.58) and pack-years (p < 0.02).
Intermediate	65	29.2	26.1	112	
High	67	53.7	34.7	155	
Shortness of breath‡	259	7.3			
Low	127	3.1	6.4	48	p > 0.50 for diesel tenure; adjusted for age (p > 0.30) and pack-years (p > 0.40).
Intermediate	65	7.7	6.3	122	
High	67	14.9	10.0	149	

* Cough = answering yes to the question, "Do you usually cough on most days for as much as 3 months each year?"

† Phlegm = answering yes to the question, "Do you usually bring up phlegm for as much as 3 months each year?"

‡ Shortness of breath = answering yes to the question, "Do you get short of breath when walking with other people of your own age on level ground?"

TABLE 3
SUMMARY OF MULTIPLE REGRESSION MODEL* OF PULMONARY FUNCTION OF WHITE MALE SALT MINERS†

	FVC	FEV ₁	PEFR	V̇max ₅₀	V̇max ₇₅	Helium/Oxygen	
						ΔV̇max ₅₀	ΔV̇max ₇₅
n	257	257	209	209	209	189	189
Age (β ₁), yr	-26 (4)‡	-31 (4)‡	-26 (12)§	-31 (10)¶	-27 (4)‡	0.20 (0.14)¶	-0.06 (0.18)¶
Height (β ₂), cm	39 (6)‡	34 (5)‡	90 (17)‡	45 (15)§	25 (6)‡	0.27 (0.21)¶	0.30 (0.27)¶
Pack-years (β ₃)	-3 (2)¶	-6 (2)‡	-10 (5)§	-11 (4)§	-5 (2)§	-0.16 (0.06)§	-0.16 (0.08)§
Mine (β ₄)							
A	5.17 (0.15)§	3.96 (0.14)**	9.79 (0.37)‡	4.35 (0.33)¶	1.52 (0.14)¶	28.5 (4.4)‡	7.4 (5.8)**
B	5.20 (0.14)§	3.95 (0.12)**	-	-	-	-	-
C	4.92 (0.12)§	3.80 (0.11)**	-	-	-	-	-
D	4.89 (0.06)§	3.73 (0.06)**	8.45 (0.15)‡	3.95 (0.13)¶	1.28 (0.05)¶	30.6 (1.8)‡	19.5 (2.4)**
E	4.79 (0.07)§	3.62 (0.06)**	9.26 (0.17)‡	4.00 (0.15)¶	1.28 (0.06)¶	41.4 (1.9)‡	21.7 (2.4)**
Diesel tenure-years (β ₅)	-6 (6)¶	0.7 (5)¶	-15 (15)¶	7 (14)¶	3 (7)¶	-0.13 (0.18)¶	-0.08 (0.24)¶
r ²	0.46	0.56	0.36	0.23	0.46	0.11	0.07
Units	ml or L	ml or L	ml/s or L/s	ml/s or L/s	ml/s or L/s	%	%

Definition of abbreviations: FVC = forced vital capacity; FEV₁ = forced expiratory volume in one second; PEFR = peak expiratory flow rate; V̇max₅₀ and V̇max₇₅ = maximal flow after exhalation of 50 and 75% of FVC.

* Model: Pulmonary Function = α + β₁(age) + β₂(height, cm) + β₃(pack-years) + β₄(tenure) + β₅(diesel tenure).

† Numbers in parentheses are standard errors.

‡ p < 0.0005.

§ p < 0.05.

¶ p < 0.005.

¶ p > 0.10, not significant.

** p < 0.10.

nary function compared to the low and/or medium diesel exposure categories.

External Comparisons

The comparison and study populations of white males were similar in age and smoking characteristics (table 5). The age- and smoking-adjusted prevalence of cough and phlegm in the study population was significantly higher (45 and 59%, respectively) than in the comparison population. The adjusted prevalence of dyspnea was about the same. There was no consistent association of smoking and respiratory symptoms. The higher exposure groups consistently had a higher observed/expected ratio, and the differences between high and low exposure categories were statistically significant for cough and phlegm (table 6).

The FVC and FEV₁ in the 2 populations were very similar and not significantly different from 100. Observed flow rates were less than predicted but there was no relationship with exposure (table 7).

Discussion

To evaluate the association of diesel exposure with respiratory symptoms and pulmonary function, two kinds of comparisons were made. First, salt workers with high diesel exposure were compared with salt workers with low diesel exposure. This internal compari-

son showed a statistically significant association of increased phlegm with increasing exposure. Cough and dyspnea showed a similar trend, but the associations were not significant. Pulmonary function showed no association with diesel exposure.

Second, the study population was compared with a group of nonexposed "blue collar" workers selected for control purposes in respiratory disease studies. After indirect adjustment for age and smoking, the overall prevalence of cough and phlegm was elevated in the study population, but dyspnea was not; FEV₁ and FVC were within 4% of expected.

In this study we found no significant

relationship between diesel exposure and change in pulmonary function, cough, or dyspnea. It is possible that there was in fact a significant dose-response relationship that was not significant because of the small sample size. In the case of pulmonary function, this is not so as pulmonary function was better in the high than in the low exposure groups, and the intermediate exposure group had the highest pulmonary function. For cough and dyspnea there was a trend for the prevalence of symptoms to increase with exposure, but we accepted the null hypothesis of no difference between exposure groups. What were the chances of a Type II error, i.e., of incorrectly

TABLE 4
RESIDUAL PULMONARY FUNCTION OF WHITE MALE SALT MINERS BY DIESEL EXPOSURE CATEGORY, ADJUSTED FOR AGE, HEIGHT, PACK-YEARS, AND MINE

	Diesel Exposure Category		
	Low	Intermediate	High
n	126	64	67
FVC, ml	0 (641)*	33 (556)	-32 (618)
FEV ₁ , ml	-7 (578)	2 (524)	10 (487)
n	78	64	67
PEFR, ml/s	-87 (1,533)	334 (1,349)	-218 (1,455)
V̇max ₅₀ , ml/s	-43 (1,226)	13 (1,405)	37 (1,242)
V̇max ₇₅ , ml/s	-20 (514)	28 (670)	-4 (410)
He-O ₂ , n	70	58	61
ΔV̇max ₅₀ , %	-1.0 (11.5)	1.4 (15.1)	-0.2 (21.6)
ΔV̇max ₇₅ , %	-0.8 (19.4)	-0.4 (20.1)	1.3 (24.6)

For definition of abbreviations, see table 3.

* Numbers in parentheses are standard deviations.

TABLE 5
DEMOGRAPHIC CHARACTERISTICS OF "BLUE COLLAR" COMPARISON
POPULATION AND STUDY POPULATION (ALL WHITE MALES)

	Nonsmoker	Ex-smoker	Smoker
"Blue collar"			
n, %	207 (25)*	194 (23)	442 (52)
Age, yr	35 (14)	44 (14)	36 (13)
Height, cm	174 (7)	174 (7)	173 (7)
Cigarettes/day	—	23 (15)	23 (11)
Pack-years	—	21 (23)	23 (19)
Study population			
n, %	50 (19)	59 (23)	150 (58)
Age, yr	37 (14)	45 (13)	39 (13)
Height, cm	176 (6)	177 (8)	177 (6)
Cigarettes/day	—	26 (18)	25 (13)
Pack-years	—	25 (25)	27 (22)
He-O ₂ , n	33	45	111
$\Delta V_{max_{50}}$, %	2.4 (19.7)	0.5 (14.5)	-0.9 (16.0)
$\Delta V_{max_{75}}$, %	4.4 (24.1)	2.2 (21.7)	-2.2 (20.2)

For definition of abbreviations, see table 3.

* Numbers in parentheses are standard deviations.

concluding there was no difference? For cough, there was a 9% chance that the 19% difference between low and high exposure groups was a true difference. For dyspnea there was a 44% chance that the 12% difference in prevalence was significant. For both symptoms we concluded there was no difference.

Estimating the effects of diesel exposure on respiratory symptoms and pulmonary function in this population presents several problems. (1) Although NaCl is not considered a respiratory hazard and is often used as a control aerosol in clinical and animal trials, it has some irritant potential, at least to the skin (12). In this study, the question arises as to whether NaCl could cause an increased cough and phlegm production. (2) There were no local or contemporary controls with which to compare these workers. Thus the effect

of differences in geography (both regional and urban-rural) and lifestyle that exist between the mines and between the salt and "blue collar" population cannot be resolved. Several subsidiary issues related to the biologic significance of differences in symptoms and pulmonary function are important and need consideration.

Symptoms. There is clearly a statistically significant dose-response relation between phlegm and diesel tenure. The overall prevalence was higher than expected when compared with that in "blue collar" workers, with a threefold excess occurring in the high exposure group. Phlegm is caused by the inhalation of dust and certain gases and fumes. It "does not cause respiratory disability and . . . usually disappears when occupational exposure ceases" (13). Although phlegm (or cough and phlegm) is generally elevated among

workers in the dusty trades (13, 14), there is not usually a dose-response relation (13). The occurrence of phlegm in this population is unusual as there was a dose-response relation, and the association was stronger with diesel tenure than with smoking status (11). Although we know of no evidence one way or the other of the effect of NaCl on mucous membranes, diesel exhaust has been shown to cause in animals hypertrophy of goblet cells (14) and reduced tracheal clearance (15).

The validity of symptoms based on a questionnaire is difficult to evaluate (16). Few studies have reported the relation of symptoms and physiologic indexes. Dosman and coworkers (17) found little or no correlation of "early tests" of mild obstruction with symptoms of cough, phlegm, wheezing, and shortness of breath.

Samet and associates (18) questioned the utility of symptoms from a respiratory questionnaire as they are affected by biased reporting that reflect workers' attitudes and "provide confirmation of exposure to cigarette smoke but little, if any, additional information about airways function." Wright and coworkers (19) found that the relation between respiratory symptoms and pulmonary function was good in workers without hypochondriasis, with high job satisfaction, and low life stress. The lack of a consistent relation between pulmonary function and symptoms in this population (11) suggests possible bias in symptom reporting.

Eye irritation was not included in our questionnaire but was experienced by the survey crew at the heavily dieselized mines. Battigelli (5) found that eye irritation was a more sensitive indicator of diesel exposure than increases in airway resistance. We suggest, therefore, that in future studies irritation be studied as an early indicator of health effects of diesel exposure.

Pulmonary function. In the salt miner population, pulmonary function has not been associated with estimates of particulate and NO₂ exposure (11) nor to the more direct measure of diesel exposure (tenure) used in this report. Even the presumably more sensitive measures of obstruction using He-O₂ were not related to chronic or acute (unpublished observations) exposures.

The small reductions in percent predicted pulmonary function deserve further comment. Glindmeyer (20) recently pointed out the extreme variability in different studies of predicted FVC and

TABLE 6
OBSERVED AND EXPECTED RATES OF COUGH, PHLEGM, AND DYSPNEA
AMONG SALT WORKERS COMPARED WITH THOSE AMONG
"BLUE COLLAR" WORKERS, INDIRECTLY ADJUSTED FOR
AGE AND SMOKING

	n	Observed	Expected	O/E	95% Confidence Intervals
Cough	259	63	43	145	113-185
Low diesel exposure	127	23	21.6	107	68-160
Intermediate	65	15	11.8	127	71-210
High	67	25	10.0	250	162-369
Phlegm	259	73	46.5	159	124-197
Low diesel exposure	127	18	22.7	79	47-125
Intermediate	65	19	12.4	153	92-240
High	67	36	11.4	316	214-409
Shortness of breath	259	18	19.3	93	55-147
Low diesel exposure	127	4	8.7	46	12-117
Intermediate	65	5	4.7	107	35-250
High	67	9	5.9	152	69-288

TABLE 7
PERCENT PREDICTED PULMONARY FUNCTION OF SALT MINER POPULATION COMPARED WITH THAT IN
"BLUE COLLAR" NORMAL POPULATION, ADJUSTED FOR AGE, HEIGHT, AND SMOKING

	Percent Predicted Pulmonary Function						
	n	FEV ₁	FVC	n	PEFR	$\dot{V}_{max_{50}}$	$\dot{V}_{max_{75}}$
Smoking status							
Nonsmoker	50	98.1 (14.0)*	101.2 (13.3)	39	95.9 (12.6)	86.3 (23.6)	72.4 (24.1)
Ex-smoker	58	97.2 (15.4)	97.2 (15.9)	50	95.2 (17.4)	88.9 (30.1)	85.1 (39.9)
Smoker	150	97.7 (15.7)	100.9 (13.1)	121	94.8 (17.8)	86.7 (30.8)	79.7 (35.2)
Diesel exposure							
Low	126	99.1 (15.8)	102.2 (14.2)	78	96.2 (18.0)	86.7 (28.0)	79.7 (30.1)
95% confidence intervals		96.3-101.9	99.7-104.7		98.1-99.3	81.8-91.6	74.4-85.0
Intermediate	65	96.4 (13.7)	99.7 (11.8)	65	97.3 (15.6)	84.9 (29.6)	77.5 (37.5)
95% confidence intervals		93.8-99.7	96.8-102.6		93.5-101.1	77.7-92.1	68.4-86.6
High	67	96.2 (15.8)	96.6 (14.4)	67	91.8 (16.2)	89.8 (30.8)	81.6 (37.4)
95% confidence intervals		92.4-100.0	93.2-100.1		87.9-95.7	82.4-97.2	72.6-90.6

For definition of abbreviations, see table 3.

* Numbers in parentheses are standard deviations.

FEV₁ values. Mean predicted FVC varied by over a liter (about 20%), whereas the predicted decline with age varied by 60% (14 to 36 ml/yr) in the 16 studies surveyed. Mean predicted FEV₁ varied by about 16%, and age coefficients ranged from 23 to 36 ml/year (45%).

The salt population mean values for FEV₁ and FVC fell well within the 16 to 20% range of both Knudson and co-workers (21) (the normal population recommended by Glindmeyer) and the "blue collar" population. Age coefficients were also generally within this range, although the decline among smokers was greater than -36 ml/yr, and confirms the already well-recognized detrimental effects of smoking on pulmonary function (see table 8). Thus the 2 to 4% reduction in percent predicted FEV₁ and FVC of the salt population appears well within expected variability among unexposed populations.

The large variation seen from one

"normal" population to another, the small proportion of the variation in pulmonary function that is explained by the independent variables of age, smoking, mine, and exposure, the lack of any association of reduced pulmonary function with diesel tenure, and the small difference between the salt and comparison populations are the reasons we conclude that diesel exposure in this population did not result in reductions in pulmonary function.

In summary, phlegm was the only symptom that showed a statistically significant dose-response relation. Adjusted rates of cough and phlegm were higher than in an external comparison population and percent predicted flow rates showed a significant reduction but they were not related to exposure. Percent predicted FEV₁ and FVC reductions were small (4%) and generally not statistically significant.

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TABLE 8
COMPARISON OF PULMONARY FUNCTION

	Knudson and associates (21) (> 25 yr)		Blue Collar Workers		Salt Mine Workers	
	Mean* (L)	Decline/yr (ml)	Mean* (L)	Decline/yr (ml)	Mean* (L)	Decline/yr (ml)
FVC						
Nonsmoker	4.75	-29	4.76	-24	4.90	-29
Ex-smoker	-		4.87	-25	4.87	-27
Smoker	-		4.73	-25	4.88	-36
FEV₁						
Nonsmoker	3.84	-27	3.96	-31	3.83	-30
Ex-smoker			3.90	-36	3.84	-35
Smoker			3.71	-38	3.67	-42

For definition of abbreviations, see table 3.

* Calculated with age = 35 yr, height = 172.7 cm.

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