ENVIRONMENTAL RESEARCH 44, 6–17 (1987)

Epidemiological–Environmental Study of Diesel Bus Garage Workers: Chronic Effects of Diesel Exhaust on the Respiratory System

JOHN GAMBLE, WILLIAM JONES, AND STEPHEN MINSHALL

National Institute for Occupational Safety and Health, Appalachian Laboratories for Occupational Safety and Health, Division of Respiratory Disease Studies, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505

Received September 9, 1985

Two hundred and eighty-three (283) male diesel bus garage workers from four garages in two cities were examined to determine if there was excess chronic respiratory morbidity related to diesel exposure. The dependent variables were respiratory symptoms, radiographic interpretation for pneumoconiosis, and pulmonary function (FVC, FEV_1, and flow rates). Independent variables included race, age, smoking, drinking, height, and tenure (as surrogate measure of exposure). Exposure–effect relationships within the study population showed no detectable associations of symptoms with tenure. There was an apparent association of pulmonary function and tenure. Seven workers (2.5%) had category 1 pneumoconiosis (three rounded opacities, two irregular opacities, and one with both rounded and irregular). The study population was also compared to a nonexposed "blue-collar" population. After indirect adjustment for age, race, and smoking, the study population had elevated prevalences of cough, phlegm, and wheezing, but there was no association with tenure. Dyspnea showed a dose–response trend but no apparent increase in prevalence. Mean percent predicted pulmonary function of the study population was greater than 100%, i.e., elevated above the comparison population. These data show there is an apparent effect of diesel exhaust on pulmonary function but not chest radiographs. Respiratory symptoms are high compared to "blue-collar" workers, but there is no relationship with tenure.

INTRODUCTION

This paper is part of an industrial hygiene and morbidity study of diesel bus mechanics reporting on the environmental characteristics of the garages (Jones *et al.*, 1985) and on acute (over the work shift) changes in symptoms and pulmonary function (Gamble *et al.*, 1987). This paper presents an analysis of possible chronic health effects among the diesel bus mechanics.

Studies of the chronic respiratory health effects of exposure to diesel exhaust have largely been of mining populations. These morbidity studies have included iron miners (Jorgensen and Svensson, 1970; Pham *et al.*, 1977), metal and nonmetal miners (Attfield, 1978; Attfield and Gamble, 1983; Reger and Attfield, 1983), potash miners (Attfield *et al.*, 1982; Graham *et al.*, 1983), salt miners (Gamble *et al.*, 1983; Gamble and Jones, 1983a, b), and coal miners (Reger *et al.*, 1982; Reger and Hancock, 1982; Ames *et al.*, 1984). These workers have confounding exposure to mine dust, and no effects were found that could clearly be attributed to diesel exhaust. Battigelli *et al.* (1964) found no significant differences

0013-9351/87 $3.00

in respiratory symptoms or pulmonary function of diesel locomotive repairmen compared to other railroad workers. Average tenure of the exposed population was 9.6 years, and symptoms of cough, phlegm, and dyspnea were all less than 10%. El Batawi and Noweir (1964) found that Egyptian diesel bus garage workers had some excess respiratory symptoms.

This study of 283 male diesel bus garage workers addresses the following questions: (1) What is the relation between diesel exposure and chronic morbidity (respiratory symptoms, chest radiographic findings, and pulmonary function)? This internal comparison is between workers with high and low tenure within the study population. (2) Is there an increased chronic morbidity in the diesel bus garage population compared to a "blue-collar" comparison population (external comparison)?

METHODS

The examination of each worker included a questionnaire, chest X-ray, and spirometry. The Medical Research Council respiratory symptom questionnaire containing smoking history and a drinking history was administered by trained interviewers. Each can of beer, glass of wine, and shot of liquor was assigned an alcohol content of 0.38 oz. Alcohol years is the average number of ounces of alcohol consumed per day multiplied by the number of years of consumption and is analogous to pack years (packs per day × years smoked). Alcohol per day is the average number of ounces of alcohol consumed per day and is analogous to cigarettes smoked per day. Work histories were obtained from Department of Transportation personnel records. There are no past environmental measurements at any of the garages. Garages C and D are new and the past exposures in the garages they replaced are unknown. Tenure is therefore the exposure variable used. Standard PA chest roentgenograms were read independently by three "B" readers using the ILO U/C 1971 classification. The median of three readings was used for analysis. Flow volume curves from a minimum of five forced exhalations were recorded on magnetic tape using an Ohio 800 rolling seal spirometer. Preshift maximum forced expiratory volume in one second (FEV_1), maximum forced vital capacity (FVC), and peak flow (PKF) were used for analysis. A maximum envelope curve was used to obtain flow rates at 50 and 75% of expired FVC (FEF_{50}, FEF_{75}).

Statistical Consideration

For internal comparisons within the study population, a logistic model was used to analyze the association between respiratory symptoms and tenure, under control for age, smoking, drinking, and race. Age and duration of smoking are variables known to affect pulmonary function. They are also colinear with our measure of exposure. To isolate the relationships of tenure and pulmonary function and to avoid the problems of multicolinearity, the pulmonary function will be externally adjusted for age, height, smoking, and race by means of regression coefficients from the "blue collar" population. The response variable will be called an adjusted pulmonary function value, e.g., adj. FEV_1, and is calculated for each study individual by subtracting his race, age, height, and smoking predicted pulmonary function value from his actual value (Sussman *et al.,* 1987).

An external comparison was also made between the study population and a "blue-collar" population designed for such comparisons (Petersen and Castellan, 1984). Comparison of symptom prevalence was made after indirect adjustment for age and smoking. Age- and height-adjusted predictive equations of pulmonary function for each race and smoking category were used to calculate expected values. Observed pulmonary function in each study population member was compared with the expected value from the "blue-collar" regression. Age coefficients by race and smoking were also compared.

RESULTS

Demographic Characteristics

Mean tenure of the study population was 9 years and was higher among nonsmokers and nondrinkers but varied little by race and garage (Table 1). About 10% of the study population said they had worked in a foundry and about 10% had worked with asbestos—most for 5 years or less.

Symptoms

About one of every four workers reported chronic cough or phlegm, and there was no apparent association with tenure (Table 2). The prevalence of dyspnea was 6%. Symptom prevalences were higher among smokers, workers in garages A and B, and those with medium and high tenure. The prevalence of wheezing was 14%. There was a higher than expected prevalence among smokers and workers in garage B and a slight trend for the O/E ratio to increase with tenure. The prevalences of symptoms of chest illness and weather affecting the chest were less than 10% and there were no apparent associations with tenure. One of every three workers had a chronic stuffy nose; in garage B there was an increased prevalence of this symptom.

Chest X-Rays

There were seven workers with pneumoconiosis: three with grade 1/0 round opacities, one with 1/1 round opacities, two with 1/0 irregular opacities, and one with both round (1/1) and irregular (1/0) opacities (Table 3). There were four smokers, two nonsmokers, and one exsmoker with very few pack years. The first four workers were from garage C and the remaining three from garage D. Potential job exposures that could result in pneumoconiosis include two persons each with the occupations of grinder and machinist.

Pulmonary Function

The association of adjusted pulmonary function with tenure is summarized in Table 4A for all nonsmokers and the entire cohort. Reductions in all pulmonary function parameters except FEF_{75} are associated with increasing tenure. For example, for each year of tenure there is an estimated excess loss of 13 ml FEV_1 among both nonsmokers, and among all workers. A similar trend is observed when mean adjusted pulmonary function is calculated by tenure groups (Table 4B).

TABLE 1
DEMOGRAPHIC CHARACTERISTICS OF MALE BUS GARAGE WORKERS BY SMOKING, GARAGE, AND RACE

A. By Smoking

	Nonsmoker	Exsmoker	Smoker	Total
n	82	68	133	283
Age	36.9 (13.2)	39.8 (12.3)	37.4 (12.7)	37.8 (12.7)
Height (cm)	175.0 (7.2)	175.5 (6.7)	175.5 (7.2)	175.3 (7.1)
Weight (kg)	85.2 (14.2)	83.7 (15.8)	80.9 (17.2)	82.8 (16.1)
Years worked	10.0 (11.3)	11.2 (11.6)	6.7 (8.6)	8.7 (10.3)
Cigarettes/day	—	19.1 (13.1)	19.8 (11.7)	13.9 (13.6)
Pack years	—	13.6 (17.2)	20.7 (19.6)	12.9 (18.1)
Alcohol (oz)/day	0.59 (.77)	0.78 (0.90)	0.89 (0.93)	0.78 (0.89)
Alcohol (oz) years	8.7 (17.8)	15.1 (18.5)	14.9 (22.1)[a]	13.1 (20.2)
Nondrinkers (%)	18.3	8.8	1.5	8.1
Exdrinkers (%)	11.0	20.6	18.8	17.0
Drinkers (%)	70.7	70.6	79.7	74.9

B. By Garage

	A	B	C	D
n	55	62	68	98
Age	36.2 (12.4)	35.9 (11.3)	43.1 (15.0)	36.3 (11.2)
Years worked	7.3 (10.1)	7.5 (10.3)	10.9 (11.4)	8.8 (9.6)
Alcohol (oz)/day	0.76 (0.96)	0.74 (0.77)	0.77 (0.92)	0.81 (0.90)
Alcohol (oz) years	15.4 (26.6)	12.2 (19.5)	14.2 (21.3)	11.8 (15.4)
Nonsmokers (%)	32.7	25.8	30.9	27.6
Exsmokers (%)	32.7	22.6	17.7	24.5
Smokers (%)	34.6	51.6	51.5	48.0
Nondrinkers (%)	12.7	4.8	4.4	10.2
Exdrinkers (%)	21.8	24.2	13.2	12.2
Drinkers (%)	65.5	71.0	82.4	77.6

C. By Race

	Black	White
n (%)	139 (49)	144 (51)
Age	39.1 (12.5)	36.6 (12.9)
Tenure	8.7 (10.6)	8.8 (10.1)
Nonsmokers (%)	29	29
Exsmokers (%)	24	24
Smokers (%)	48	47

[a] One missing.

Symptoms and Pulmonary Function

Although workers with symptoms often had a lower pulmonary function than those without symptoms, the relation between pulmonary function reduction and severity of the symptoms was consistent only for dyspnea and wheezing (Table 5).

External Comparisons

The "blue-collar" comparison population was younger and had smoked less

TABLE 2

PREVALENCE AND OBSERVED/EXPECTED (O/E) MORBIDITY RATIOS OF RESPIRATORY SYMPTOMS BY EXPOSURE (TENURE) UNDER CONTROL FOR RACE, AGE, SMOKING, AND ALCOHOL CONSUMPTION

		Tenure (n)			
	All (283)	<5 years (150)	5–9 years (93)	≥10 years (40)	Comment
Cough			N.S.[a]		Smoking, $P < 0.0005$
Observed (%)	24	25	24	20	Garage, $0.05 < P < 0.10$
O/E × 100		95	104	113	
Phlegm			N.S.		Smoking, $P < 0.005$
Observed (%)	26	27	27	20	Garage, $P < 0.05$
O/E × 100		96	108	101	
Dyspnea			N.S.		Smoking and garage,
Observed (%)	8	4	10	8	$0.05 < P < 0.10$
O/E × 100		60	154	139	
Wheeze			N.S.		
Observed (%)	14	4	14	13	Garage, $P < 0.05$
O/E × 100		93	108	120	Smoking, $0.05 < P < 0.10$
Weather affect chest			N.S.		
Observed (%)	10	11	7	15	Garage, $0.05 < P < 0.10$
O/E × 100		108	65	155	
Chronic stuffy nose			N.S.		
Observed (%)	33	33	30	38	Garage, $P < 0.05$
O/E × 100		99	99	121	
Chest illness			N.S.		
Observed (%)	7	7	7	8	
O/E × 100		99	93	123	

[a] N.S.: $P > 0.10$.

than the study population (Table 6). Intensity of smoking (pack years, cigarettes per day) was not controlled for in the comparison.

The study population had higher than expected prevalences of cough, phlegm, and wheezing compared to the "blue-collar" comparison population, but there was no association with tenure. The expected prevalence of dyspnea was not elevated, but there was a trend for higher than expected prevalences in the medium- and high-exposure groups (Table 7).

Mean percent predicted pulmonary function was consistently above 100% (Table 8). However, the age coefficients from the pulmonary function regressions consistently showed a larger reduction with age in the study population compared to "blue-collar" workers. At age 30 the means calculated from the regressions for FEV_1 and FVC were larger in the bus garage population than in the "blue-collar" population. At age 50 the calculated values of FVC and FEV_1 among white and black smokers of the study population were less than those of the comparison population (Table 9).

DISCUSSION

To evaluate the relations between exposure (measured as tenure) and chronic morbidity, two kinds of comparison have been made. The first was within the

TABLE 3
CHARACTERISTICS OF DIESEL GARAGE WORKERS WITH CATEGORY 1 PNEUMOCONIOSIS

					Opacities		
Age	Tenure (years)	Smoking category	Cigarettes/day	Pack years	Round	Irregular	Nontransportation jobs
42	0.9	Nonsmoker	—	—	1/0	—	Machine repair (4 yr), roller operator (19 yr)
60	4.8	Smoker	20	44	1/1	1/0	Machinist (2 yr), mechanic (3 yr), repairing and filling acid tanks (8 yr), truck driver (20 yr), grinder (3 yr)
59	17.8	Smoker	20	37	1/0	—	*Diesel mechanic* (6½ yr), auto assembly (14 yr)
58	9.5	Exsmoker	3	2	—	1/0	Grinder (3 yr), dry cleaning route (4 yr)
61	39.8	Nonsmoker	—	—	1/1	—	Military, farming
26	6.5	Smoker	30	20	1/0	—	Machinist (½ yr), gas mechanic (3 yr)
46	12.0	Smoker	30	—		1/0	Spray painter (5 yr), car assembly (3½ yr), bronze fabricator (1½ yr), construction (½ yr), military (2½ yr)

TABLE 4

ASSOCIATION OF ADJUSTED PULMONARY FUNCTION AND TENURE AFTER ADJUSTMENT FOR AGE, HEIGHT, RACE, AND SMOKING STATUS

A. Regression of adjusted pulmonary function on tenure in years. Model: Adj PF = $\alpha + \beta$ (tenure)

	Nonsmokers		Total cohort	
	β	SE[a]	β	SE
Adj FEV_1[b]	−13.4	4.9**	−12.7	3.3****
Adj FVC	−20.9	5.8***	−17.9	3.8****
Adj Peak Flow	−31.3	17.0*	−35.2	10.6***
Adj FEF_{50}	−27.5	14.8*	−20.2	8.3**
Adj FEF_{75}	+3.8	7.3 N.S.	+3.4	3.6 N.S.

B. Mean adjusted pulmonary function by tenure

	Tenure		
	<5 years	5–9 years	≥10 years
Adj FEV_1	+245 (41)	+24 (80)	−102 (73)
Adj FVC	+332 (53)	+124 (87)	−46 (78)
Adj Peak Flow	+637 (140)	+212 (258)	−348 (230)
Adj FEF_{50}	+396 (115)	+80 (203)	−218 (163)
Adj FEF_{75}	−22 (51)	−133 (80)	−30 (75)

Note. Adj PF = observed-expected, with expected values derived from race and smoking specific "blue collar" workers, and controlling for age and height.

[a] SE in parenthesis.

[b] FEV_1 and FVC are in ml, flow rate in ml/sec.

[c] N.S. $P > 0.10$.

* $P < 0.10$.

** $P < 0.05$.

*** $P < 0.005$.

**** $P < 0.0005$.

TABLE 5

RESIDUAL LEAST-SQUARE MEAN PULMONARY FUNCTION OF DIESEL BUS GARAGE WORKERS BY SMOKING, DRINKING, AND SYMPTOMS ADJUSTED FOR AGE, HEIGHT, RACE, PACK YEARS, AND ALCOHOL YEARS[a]

	n	FVC (ml)	FEV_1 (ml)	Peak flow (ml/sec)	FEF_{50} (ml/sec)	FEF_{75} (ml/sec)
Cough						
No	163	33 (51)	52 (42)	95 (135)	106 (101)	42 (45)
Mild	43	−80 (90)	−132 (87)	110 (262)	−212 (253)	−154 (101)
Chronic	65	−30 (79)	−42 (71)	−311 (259)	−126 (189)	−4 (69)
Phlegm						
No	163	47 (50)	32 (44)	158 (138)	20 (113)	−12 (46)
Mild	37	−178 (95)	−132 (85)	−237 (310)	9 (233)	−40 (98)
Chronic	71	−15 (78)	−3 (65)	−239 (222)	−50 (161)	49 (69)
Dyspnea						
No	194	61 (45)	61 (36)	175 (120)	105 (99)	17 (43)
G-1	60	−110 (79)	−104 (80)	−289 (247)	−204 (183)	−29 (68)
G-2	17	−312 (179)	−333 (182)	−982 (619)	−475 (427)	−96 (146)
Wheezing						
No	182	9 (48)	37 (40)	202 (128)	105 (102)	27 (44)
Ever	51	58 (81)	−1 (72)	−230 (269)	−119 (210)	−42 (86)
Most days	38	−120 (115)	−175 (103)	−657 (318)	−345 (236)	−75 (78)

[a] SE in parentheses.

TABLE 6
CHARACTERISTICS OF MALE "BLUE-COLLAR" COMPARISON POPULATION BY RACE AND SMOKING[a]

	n	Age	Cigarettes/day	Pack years
White				
Nonsmokers	114	30.9 (12.7)	—	—
Exsmokers	91	41.9 (14.3)	23.4 (14.9)	19.6 (22.1)
Smokers	206	31.3 (12.4)	22.7 (10.3)	17.3 (17.3)
All	411	33.5 (13.6)	16.6 (14.4)	13.0 (18.0)
Black				
Nonsmokers	91	27.7 (10.0)	—	—
Exsmokers	38	31.9 (12.0)	10.1 (9.7)	7.4 (14.9)
Smokers	176	29.6 (9.8)	13.7 (9.6)	8.9 (10.6)
All	305	29.3 (10.2)	9.1 (10.1)	6.0 (10.4)

[a] SD in parentheses.

study population. The second was an external comparison of the study population with a nonexposed "blue-collar" population.

In the internal comparison, the prevalence of dyspnea and wheeze was higher in the groups with longer tenure. For cough, the differences were dose-related but very small; for phlegm, there were no interpretable differences. The external comparisons show about double the expected prevalences for cough, phlegm, and wheezing, but no dose–response relationships were observed. The prevalence of dyspnea was not elevated but there was a suggestion of a dose–response relationship.

Pulmonary function generally decreased with increasing tenure, except for FEF_{75}. Mean pulmonary function was not reduced in the total cohort compared to the reference population, but was reduced in the workers with 10 or more years' tenure. Reductions in FEV_1 were about 13 ml for each year employed in both smokers and nonsmokers.

Some caveats on these findings are in order. Although age and tenure were highly correlated, age and tenure are not confounded in the symptom analysis because increased age was not a risk factor for symptoms. In the pulmonary function analysis the problem of multicolinearity is avoided by using race and smoking specific regressions from an external reference population to estimate age and height adjusted for expected values.

Tenure is a surrogate of exposure to diesel exhaust. Because both high- and low-exposure jobs are given equal weight, a real dose–response relation is harder to detect and may in fact be obscured. If current job is a reflection of past exposures (with running repair jobs having higher exposure), then workers in running repair garages A and B would be considered high exposure, heavy repair garage C as low exposure, and garage D as intermediate. If this approximation is correct, dyspnea is the only symptom related to exposure.

Mean pulmonary function of diesel workers showed no overall reduction compared to "blue-collar" workers, but the increased loss with age supports the association observed with tenure.

TABLE 7
PREVALENCE OF SYMPTOMS AMONG MALE DIESEL BUS GARAGE WORKERS COMPARED TO "BLUE-COLLAR" WORKERS

	n	Observed	Observed/expected × 100 (95% C.I.)	Indirectly adjusted for:
Cough	283	68	231* (182–292)	Race, age, smoking
Low exposure	150	38	220 (156–302)	
Medium exposure	93	22	195 (122–295)	Smoking
High exposure	40	8	192 (83–378)	
Phlegm	283	74	188* (149–236)	Race, age, smoking
Low exposure	150	41	201 (145–321)	
Medium exposure	93	25	204 (132–300)	Smoking
High exposure	40	8	159 (69–313)	
Dyspnea	283	18	120 (71–189)	Race, age, smoking
Low exposure	150	6	79 (29–171)	
Medium exposure	93	9	198 (91–376)	Smoking
High exposure	40	3	166 (34–485)	
Wheezing	283	39	249* (177–341)	Race, age, smoking
Low exposure	150	21	254 (157–388)	
Medium exposure	93	13	271 (144–464)	Smoking
High exposure	40	5	275 (89–641)	

* $P < 0.05$ that O/E ratio > 100.

Exposure to individual components of diesel exhaust has been shown at some exposure level to result in irritation, respiratory symptoms, and reduced pulmonary function (Parkes, 1982; Travis and Munro, 1983). Although there are no data on the relationship between diesel particulate exposure and chest radiographic changes, inhalation of related substances suggests measurable deposition is possible. Inhalation of soot presents the potential for nonmalignant respiratory disease. Anthracosis, an innocuous form of pneumoconiosis, can result from inhalation of atmospheric soot (Spencer, 1977; Parkes, 1982). Simple pneumoconiosis has been described both in Scottish coal miners exposed to oil soot from lamps used in the coal mines (Bentley and Gergman, 1960) and in employees of an activated carbon plant (Wehr *et al.*, 1975). A prospective study of carbon black workers suggests that exposures over the TLV of 3.5 mg/m^3 can result in both radiographic changes and reduction in pulmonary function (Valic *et al.*, 1975). In summary, the potential for diesel exhaust to increase respiratory symptoms, re-

TABLE 8
PERCENTAGE PREDICTED PULMONARY FUNCTION OF BUS GARAGE WORKERS COMPARED TO "BLUE-COLLAR" WORKERS BY RACE AND SMOKING ADJUSTED FOR AGE AND HEIGHT[a]

	n	FVC	FEV_1	FEV (%)	Peak flow	FEF_{50}	FEF_{75}
All	275	103.9 (14.7)	102.7 (17.2)	96.6 (12.5)	103.0 (21.1)	102.9 (33.6)	105.9 (71.9)
Nonsmokers	80	103.6 (14.3)	102.6 (14.8)	99.2 (8.7)	106.8 (19.0)	104.8 (32.4)	107.2 (94.8)
Exsmokers	68	103.0 (17.6)	102.2 (18.9)	90.0 (13.7)	99.9 (18.3)	100.8 (30.9)	98.6 (54.0)
Smokers	127	104.5 (13.2)	103.0 (17.8)	98.6 (12.6)	102.2 (23.4)	102.9 (35.8)	109.0 (63.3)
Blacks	136	104.0 (14.3)	104.1 (16.3)	100.4 (10.4)	104.4 (21.3)	105.8 (34.5)	110.7 (83.7)
Whites	139	103.8 (15.1)	101.3 (18.0)	93.0 (13.3)	101.6 (20.9)	100.2 (32.4)	101.2 (57.9)

[a] SD in parentheses.

TABLE 9
CALCULATED VALUES OF FVC AND FEV_1 AT AGES 30 AND 50 AND CONSTANT HEIGHT OF 175 cm

	FVC (liters)		FEV_1 (liters)	
	Age 30	Age 50	Age 30	Age 50
Diesel-exposed population				
Black				
Nonsmoker	4.64	3.69	4.00	2.69
Exsmoker	4.72	3.78	3.82	2.65
Smoker	4.70	3.88	3.83	2.69
White				
Nonsmoker	5.31	3.97	4.37	3.06
Exsmoker	5.56	4.08	4.45	2.80
Smoker	5.35	4.03	4.21	2.52
Blue-collar population				
Black				
Nonsmoker	4.37	3.63	3.63	2.60
Exsmoker	4.51	3.73	2.79	1.76
Smoker	4.39	3.92	3.57	2.75
White				
Nonsmoker	5.02	4.36	4.23	3.42
Exsmoker	5.17	4.34	4.24	2.98
Smoker	5.03	4.26	4.02	2.86

duce pulmonary function, and cause pneumoconiosis as seen in chest radiography is biologically plausible at some exposure level.

The importance of confounding variables in reducing or increasing the strength of an association is lessened if the risk is high. A way of expressing the strength of association is the elevation of the observed/expected ratios. Monson (1980) proposed that 1.2–1.5 is a weak association, 1.5–3.0 is a moderate association, and greater than 3 is a strong association. The only strong associations observed were for cough and phlegm among smokers compared to nonsmokers; exsmokers showed a moderately increased risk for cough and phlegm. Smokers were at increased risk for all symptoms. Dyspnea showed a moderate association with tenure. All other symptoms showed either no or a weak association with tenure. Diesel-exposed workers compared to "blue-collar" workers were at moderate risk of cough, phlegm, and wheezing, but no increased risk of dyspnea. Among the independent variables analyzed, smoking was the most consistent and strongest risk factor for symptoms.

The results of the symptom analysis are not consistent. In the internal comparison only dyspnea showed more than a weak association with tenure; however, no increased risk was observed in the external comparisons. The diesel-exposed workers had an increased prevalence of the other symptoms compared to "blue-collar" workers, but there was no dose–response relationship. Thus there is no convincing pattern suggesting a causal relationship between diesel exposure and respiratory symptoms.

The pattern for pulmonary function is somewhat clearer. Reduced pulmonary function consistently showed an association when age and height adjusted pulmonary function variables are used to reduce the effect of multicolinearity. In the external comparisons with nonexposed "blue-collar" workers, pulmonary function was elevated above expected, but there was a greater than expected loss with age.

The prevalence of pneumoconiosis from the chest radiographs was too low to formally analyze, could have been a result of other exposures, and were borderline diagnostically (<½).

Based on the known effects of the diesel constituents, the concern about the chronic effects of diesel exhaust on the respiratory system is a legitimate one. The epidemiological studies of diesel-exposed workers do not provide support for this concern, although the number of such studies is small and they are cross-sectional in design and generally involve confounding occupational exposures. This study is consistent with the mining studies in showing small increases in the prevalence of symptoms, no increased pneumoconiosis, and no reduction in mean pulmonary function; it is unlike them in showing a reduction in pulmonary function associated with exposure.

From this study we conclude that there may be some chronic effects on the respiratory health of the diesel bus garage workers, e.g, higher than expected prevalence of cough, phlegm, and wheezing and an increased loss in pulmonary function associated with tenure.

REFERENCES

Ames, R. G., Reger, R. B., and Hall, D. S. (1984). Chronic respiratory effects of exposure to diesel emissions in coal mines. *Arch. Environ. Health* **39**, 389–394.

Attfield, M. D. (1978). The effect of exposure to silica and diesel exhaust in underground metal and nonmetal miners. *In* "ACGIH Conference on Mining and Tunneling, Denver, CO, November, 1978," pp. 129–135.

Attfield, M. D., and Gamble, J. F. (1983). *In* "A Review of the Epidemiological Evidence Concrning the Respiratory Health Effects of Mineral Dust and Diesel Fumes in Potash Technology" (R. M. McKercher, Ed.). Program Press, Toronto.

Attfield, M. D., Trabant, G. D., and Wheeler, R. W. (1982). Exposure to deisel fumes and dust at 6 potash mines. *Ann. Occup. Hyg.* **26**, 817–831.

Battigelli, M. C., Mannella, R. J., and Hatch, T. F. (1964). Environmental and clinical investigation of workers exposed to diesel exhaust in railroad engine houses. *Ind. Med. Surg.* **33**, 121–124.

Bentley, R. A., and Gergman, I. (1960). Candle or oil soot as a cause of pneumoconiosis in coal miners. *Ann. Occup. Hyg.* **134**, 109–1113.

El Batawi, M., and Noweir, M. H. (1964). Health problems resulting from prolonged exposure to air pollution in diesel bus garages. *Ind. Health* **4**, 1–10.

Gamble, J., and Jones, W. (1983a). Chronic health effects of exposure to diesel emissions among salt miners. *Ann. Amer. Conf. Gov. Ind. Hyg.* **4**, 73–83.

Gamble, J., and Jones, W. (1983b). Respiratory effects of diesel exhaust in salt miners. *Amer. Rev. Respir. Dis.* **128**, 389–394.

Gamble, J. F., Jones, W., and Hudak, J. (1983). An epidemiological study of salt miners in diesel and nondiesel mines. *Amer. J. Ind. Med.* **4**, 435–458.

Gamble, J. F., Jones, W. G., and Minshall, S. (1985). Epidemiological–environmental study of diesel bus garage workers: Acute effects of diesel exhaust on the respiratory system. *Environ. Res.* **42**, 201–214.

Graham, B. L., Dosman, J. A., and Cotton, D. J. (1983). "Lung Function and Respiratory Symptoms in Potash Workers: Abstract in Potash Technology, Mining Processing, Maintenance, Transportation, Occupational Health and Safety, Environment" (R. M. McKercher, Ed.). Perganion Press, Toronto.

Jones, W., Gamble, J., Piacitelli, G. (1985). "Environmental Study of Diesel Bus Repair Shops." AIH Conference, May 19–24, 1985, Las Vegas, Nevada.

Jorgensen, H., and Svensson, A. (1970). Studies on pulmonary function and respiratory tract symptoms of workers in an iron mine where diesel trucks are used underground. *J. Occup. Med.* **12**, 348–354.

Monson, R. R. (1980). "Occupational Epidemiology." CRC Press, Boca Raton, FL.

Parkes, W. R. (1982). "Occupational Lung Disorders," 2nd ed. Butterworths, London.

Petersen, M., and Castellan, R. (1984). Prevalence of chest symptoms in nonexposed blue collar workers. *J. Occup. Med.* **26**, 367–374.

Pham, Q. T., Mur, J. M., Biegbeder, R., Denian, R., and Leonet, O. (1977). Long-term effects of low concentrations of noxious gases on the respiratory system: Results of an epidemiological study among iron ore miners in Lorraine (France). *Rev. Epidem. Sante Publ.* **25**, 255–274.

Reed, D., McGee, D., Yano, K., and Hankin, J. (1985). Diet, blood pressure, and multicolinearity. *Hypertension* 7, 405–410.

Reger, R. B., and Attfield, M. D. (1983). Diesel emissions and associated respiratory health effects in mining. *In* "Health Issues Related to Metal and Nonmetallic Mining" (W. L. Wagner, W. N. Rom, and J. A. Merchant, Eds.). Butterworth, Boston.

Reger, R. B., and Hancock, J. (1982). Coal miners exposed to diesel exhaust. *In* "Health Implications of New Energy Technologies" (W. N. Rom and V. E. Archer, Eds.). Pp. 213–232. Ann Arbor Science Pub., Ann Arbor, Mich.

Reger, R., Hancock, J., Hankinson, J., Hearl, F., and Merchant, J. (1982). Coal miners exposed to diesel exhaust emissions. *Ann. Occup. Hyg.* **26**, 799–815.

Spencer, H. (1977). "Pathology of the Lung," 3rd ed. Pergamon, New York.

Sussman, N. B., Townsend, M. C., and Mazumdur, S. (1987). Multicolinearity and multiple regression analysis in occupation respiratory studies. Submitted for publication.

Travis, C. C., and Munro, N. B. (1983). "Assessment of Potential Health Effects of Light-Duty Diesel Exhaust." Oak Ridge National Laboratory, ORNL/PPA-83/4, July, 1983.

Valic, F., Beritic-Stahaljak, D., and Mark, B. (1975). A follow-up study of functional and radiologic lung changes in carbon black exposure. *Int. Arch. Arbeitsmed.* 34, 51–63.

Wehr, K. L., Johanson, W. G., Chapman, J. S., and Pierce, A. K. (1975). Pneumoconiosis among activated carbon workers. *Arch. Environ. Health* **30**, 578–583.