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BRIEF COMMUNICATION

Exposure to Diesel Exhaust in the Trucking Industry and Possible Relationships With Lung Cancer

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We previously reported that long-term truck drivers and mechanics in the Teamsters Union had higher lung cancer risks than Teamsters outside the trucking industry. We now summarize results from an industrial hygiene survey of current exposures to diesel exhaust in the trucking industry, and relate these to our prior results pertaining to lung cancer risk. © 1992 Wiley-Liss, Inc.

Key words: diesel exposures, trucking, industrial hygiene data, lung cancer

INTRODUCTION

In 1990, we published the results of a nested case-control study of lung cancer in the Teamsters Union [Steenland et al., 1990]. We estimated the lung cancer risk of workers in different job categories in which exposure to diesel exhaust was likely. Diesel exhaust has been shown to be a lung carcinogen in rodent studies [Ishinishi et al., 1986], and also has been implicated as a lung carcinogen in several recent epidemiologic studies [Boffetta et al., 1988; Garshick et al., 1987]. We have now completed an industrial hygiene study in which diesel exhaust exposure levels were estimated for current Teamsters [Zaebst et al., 1991] employed in the same job categories considered in the epidemiologic study. The purpose of this communication is to discuss our epidemiologic findings in the context of the industrial hygiene survey results.

RESULTS OF THE EPIDEMIOLOGIC STUDY

The epidemiologic study consisted of 996 cases (lung cancer) and 1,085 controls, all of whom were Teamsters who had died in 1982–1983 with 20 or more years tenure in the Union. The nonexposed population was defined as those employed in Teamster jobs unlikely to have had exposure to diesel exhaust. The exposed groups

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were road drivers, local drivers, mechanics, and dockworkers. Work history was available from two sources (Teamsters records and next-of-kin interviews), and two separate analyses were conducted. For each analysis, job categories were defined by the longest held job. Analyses from the Teamsters' data were restricted to the period after the introduction of diesel trucks (late 1950s), and truck drivers were divided between road drivers (presumably diesel trucks) and local drivers (presumably gasoline trucks). Analyses of truck drivers using next-of-kin data were conducted by type of truck (gasoline or diesel) driven by the decedent, because next-of-kin were able to provide this information. Odds ratios, controlled for smoking and other risk factors, were 1.27 for road drivers, 1.31 for local drivers, 1.69 for mechanics, and 0.92 for dockworkers, based on Teamster work history. The corresponding odds ratios based on next-of-kin work history were 1.42 for diesel truck drivers, 1.22 for gasoline truck drivers, 1.35 for mechanics, and 0.93 for dockworkers. None of these odds ratios achieved statistical significance. However, odds ratios for road drivers (or diesel drivers) showed significant increasing trends with increasing duration of employment using either Teamster or next-of-kin data. Those with longest employment had odds ratios of 1.55 (95% confidence interval [CI] 0.97–2.47) based on Teamster data (18+ years employment) and 1.89 (95% CI 1.04–3.42) based on next-of-kin data (35+ years employment).

Thus, results from the case-control study indicated that mechanics experienced the highest risks and dockworkers the lowest. Road and local drivers were somewhere in between, but road drivers showed increased risk with increased duration of employment. Several facts are important when considering these results. Road drivers began driving diesel trucks in the late 1950s, but local drivers generally drove gasoline trucks until the mid or late 1970s. Mechanics working on diesel engines also had exposure to asbestos in the brake linings. Dockworkers have worked with propane-powered forklifts until recently, when some companies have switched to diesel-powered forklifts.

RESULTS OF THE INDUSTRIAL HYGIENE SURVEY

The findings of the industrial hygiene survey are generally consistent with the epidemiologic study, although the survey could not estimate historical diesel exposure in the industry. In the hygiene survey, elemental carbon (a fraction of the particulate phase of the exhaust) was used as a surrogate for diesel exposure. Elemental carbon generally was found to represent about 20% of the total respirable particulate, in side-by-side samples analyzed by linear regression. Elemental carbon is characteristic of diesel particulate and its measurement is generally unaffected by tobacco smoke. Personal samples were taken, and most of the men sampled were nonsmokers.

The industrial hygiene survey found that mechanics had the highest exposures to elemental carbon (26.6 $\mu g/m^3$, n = 80). Road drivers averaged 5.1 $\mu g/m^3$ (n = 72), local drivers averaged 5.4 $\mu g/m^3$ (n = 56), and dockworkers using propane forklifts averaged 1.6 $\mu g/m^3$ (n = 12). Residential background samples averaged 1.4 $\mu g/m^3$ (n = 23) and roadway background averaged 3.4 $\mu g/m^3$ (n = 21). Road drivers averaged 7.6 $\mu g/m^3$ in the summer, when roadway levels also increased to an average 5.4 $\mu g/m^3$ (but residential background levels remained about the same as 1.1 $\mu g/m^3$). Thus, drivers apparently received much of their current exposures from the

roadway background, rather than directly from their engines. Historical exposures may have been higher and more related to the characteristics of the driver's truck.

DISCUSSION

In our epidemiologic study, we examined only job categories with presumed diesel exhaust exposure, and concluded that mechanics and long-term road drivers may have had an increased lung cancer risk compared to nonexposed Teamsters. The results of the industrial hygiene survey of current exposures in the trucking industry suggest that mechanics and long-term drivers may have had higher exposure to diesel exhaust than workers in jobs without any diesel exhaust exposure. These findings, therefore, lend support to the hypothesis that the observed increased lung cancer risk for mechanics and long-duration drivers is related to diesel exhaust exposure. Unfortunately, critical data on historical exposures are still unavailable.

Overall, current exposures to diesel exhaust in the trucking industry are generally low compared to some occupational exposures (e.g., miners in enclosed spaces), but are still measurably higher than background levels of the general population. In the railroad industry, the average exposure to respirable particulate, adjusted for tobacco smoke, ranged from 42–155 $\mu g/m^3$ in a recent survey [Woskie et al., 1988]. Truck drivers averaged about 5 $\mu g/m^3$ of elemental carbon, which represents approximately 25 $\mu g/m^3$ of respirable particulate. Measurements of diesel exhaust in mines, to date, have been in terms of submicrometer dust, which is not directly comparable to either respirable particulate or elemental carbon. However, available measurements [McCauley and Cocalis, 1986] indicate levels of exposure are likely to be substantially higher in mines than either truck driver or railroad worker exposures.

Our study suggests an excess lung cancer risk of about 50% for those with presumed highest levels of diesel exhaust exposure (long-term drivers mechanics) compared to nonexposed Teamsters. Similarly, railroad workers historically exposed to diesel exhaust have been shown to have an approximately 50% excess risk of lung cancer compared to nonexposed railroad workers, after adjustment for smoking [Garshick et al., 1987]. The trucking industry and the railroads are the only two industries in which there are both published industrial hygiene data and published epidemiologic data on lung cancer, although in both instances, the industrial hygiene data are current rather than historical, and are not linked to the actual subjects studied epidemiologically. Other attempts to systematically assess lung cancer risk by estimated exposure to diesel exhaust in a particular workplace include a nested case-control study of Swedish bus garage workers in which industrial hygienists estimated past exposures taking into account ventilation controls, number of buses serviced, etc. [Gustavsson et al., 1990]. In this study, those with high levels of estimated exposure had a significantly increased risk compared to those with low levels (odds ratios 2.4, 95% CI 1.3–4.5). Recent findings from a case-control study of Swedish dockworkers have also shown a significantly increased risk (odds ratio 2.24, 95% CI 1.02–4.93) for those with higher historical exposure to diesel exhaust as estimated by past fuel consumption, but again, actual sampling data are lacking [Emmelin et al., 1991]. There are no published studies of diesel-exposed miners, the occupational group with the highest exposures, although at least one epidemiologic study is currently underway.

The lack of actual exposure data on the studied population is typical of retro-

spective studies, and is even more of a problem in the case of diesel exhaust because of the lack of historical sampling data and lack of a standard method of measuring diesel exhaust. Inadequate historical exposure data in diesel exhaust studies remain a major limitation in evaluating the epidemiology to date. Nevertheless, the positive animal data, coupled with the suggestive epidemiologic data, support the hypothesis that whole diesel exhaust may be a carcinogen in humans.

REFERENCES

Boffetta P, Stellman S, Garfinkel L (1988): Diesel exhaust exposure and mortality among males in the American Cancer Society Prospective Study. Am J Ind Med 14:403–415.

Emmelin A, Nystrom L, Wall S (1991): Lung cancer, smoking and diesel exhaust exposure, presented at the 8th International Symposium on Epidemiology in Occupational Health, Paris, France, September 10–12.

Garshick E, Schenker M, Munoz A, Segal M, Smith TJ, Woskie SR, Hammond SK, Speizer F (1987): A case-control study of lung cancer and diesel exposure in railroad workers. Am Rev Respir Dis 135:1242–1248.

Gustavsson P, Plato N, Lidstrom E, Hogstedt C (1990): Lung cancer and exposure to diesel exhaust among bus garage workers. Scan J Work Environ Health 16:348–354.

Ishinishi N, Koizumni A, McClellan R, Stober W (eds) (1986): "Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust." New York: Elsevier.

McCauley M, Cocalis J (1986): Diesel particulate measurement techniques for use with ventilation control strategies in underground coal mines. Ann Am Conf Gov Ind Hyg 14:271–281.

Steenland K, Silverman D, Hornung R (1990): Case-control study of lung cancer and truck driving in the Teamsters Union. Am J Public Health 80:670–674.

Woskie SR, Smith TJ, Hammond SK, Schenker MB, Garshick E, Speizer FE (1988): Estimation of the diesel exhaust exposure of railroad workers I, current exposure. Am J Ind Med 13:381–394.

Zaebst D, Clapp D, Blade L, Marlow D, Steenland K, Hornung R, Scheutzle D, Butler J (1991): Quantitative determination of trucking industry workers exposures to diesel exhaust particles. Am J Ind Hygiene 52:529–541.