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Mortality Among California Highway Workers

Neil Maizlish, PhD, Jay Beaumont, PhD, and Jim Singleton, MS

Standardized proportional mortality ratios (PMR) were computed for a population of highway workers. Hazards of highway maintenance work include exposure to solvents, herbicides, asphalt and welding fumes, diesel and auto exhaust, asbestos, abrasive dusts, hazardous material spills, and moving motor vehicles.

Underlying cause of death was obtained for 1,570 workers who separated from the California Department of Transportation between 1970 and 1983, and who died in California between 1970 and 1983 (inclusive). Among 1,260 white males, the major findings were statistically significant excesses of cancers of digestive organs (PMR = 128), skin (PMR = 218), lymphopoietic cancer (PMR = 157), benign neoplasms (PMR = 343), motor vehicle accidents (PMR = 141), and suicide (PMR = **154).** Black males (N = 66) experienced nonsignificant excesses of cancer of the digestive organs (PMR = 191) and arteriosclerotic heart disease (PMR = 143). Among 168 white females, deaths from lung cancer (PMR = 189) and suicide (PMR = 215) were elevated. White male retirees, a subgroup with 5 or more years of service, experienced excess mortality due to cancers of the colon (PMR = 245), skin (PMR = 738), brain (PMR = 556), and lymphosarcomas and reticulosarcomas (PMR = 514). Deaths from external causes (PMR = 135) and cirrhosis of the liver (PMR = 229) were elevated among white males with a last job in landscape maintenance. White males whose last job was highway maintenance experienced a deficit in mortality from circulatory diseases (PMR = 83) and excess mortality from emphysema (PMR = 250) and motor vehicle accidents (PMR = 196). Further epidemiologic and industrial hygiene studies are needed to confirm the apparent excess mortality and to quantify occupational and nonoccupational exposures. However, reduction of recognized hazards among highway maintenance workers is a prudent precautionary measure.

Key words: cancer, accidents, herbicides, asphalt, solvents

INTRODUCTION

In 1985, approximately 93,600 workers were employed by state departments of transportation to maintain the 681,999 miles of the basic intercity highway network in the United States [Transportation Research Board, 1986; Smith, 19861. These workers are potentially exposed to numerous health and safety hazards, yet chronic health effects among highway maintenance workers have not been widely studied.

Recognized hazards of highway maintenance and/or traffic control work include exposure to asbestos, hot asphalt and asphalt fumes, Portland cement, solvents,

Occupational and Environmental Health Unit, University of California, Davis
Address reprint requests to Neil Maizlish, California Department of Health Services, 2151 Berkeley Way, Room 504, Berkeley, CA 94704.
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pesticides, welding fumes, ultraviolet radiation, carbon monoxide, hydrogen sulfide, lead, automobile and diesel exhaust, silica dust from abrasive blasting, various hazardous materials from highway spills, noise, moving motor vehicles and equipment, excessive heat, cold, and vibration, animal and insect bites, parasites, vector-borne diseases, and toxic plants (Table I).

Of particular concern are cancer risks that have been associated with hazardous materials used in highway maintenance work. Lung cancer has been implicated in occupational exposure to asbestos, coal tar among roofers, asphalt production, welding fumes, and diesel exhaust [NIOSH, 1980; Hammond et al, 1976; Silverstein et al, 1985a; Wilson, 1984; Beaumont et al, 1981; Schenker, 1980, NIOSH, 1977a]. Cancers of the digestive organs have been associated with asbestos, coal tar pitch volatiles, and cement [Goldsmith, 1982; Hammond et al, 1976; Silverstein et al, 1985a; McDowall, 1984]. Leukemia has been linked to benzene, agricultural and landscaping work, and coal tar pitch volatiles [Infante et al, 1977; Fasal et al, 1968; Milham, 1971; Blair and Thomas, 1979; Blair et al, 1985; Burmeister et al, 1983; Cantor and Blair, 1984; Cantor et al, 1985; Pearce et al, 1986; Silverstein et al, 1985]. Multiple myeloma has been found among agricultural workers [Pearce et al, 1985; Cantor et al, 1984]. Non-Hodgkin's lymphomas and soft tissue cancers have been associated with pesticides, particularly with phenoxyacetic herbicides [Hardell and Sandrom, 1979; Eriksson et al, 1981; Hoar et al, 1986; Schumacher, 1985; Hardell et al, 1981].

The present study of the mortality experience of employees of the California Department of Transportation (CalTRANS) was undertaken as a surveillance exercise to address concerns raised by these reports in the literature. Standardized proportional mortality analyses are particularly useful as tools for mortality surveillance and hypothesis generation. The following health outcomes, based on previous reports, were specifically of concern prior to conducting the study: 1) lymphopoietic cancers in landscaping and/or in the use of bituminous materials; 2) soft tissue sarcoma in landscaping involving potential exposure to phenoxyacetic herbicides; 3) lung cancer in workers exposed to bituminous materials; and 4) digestive organ cancers in workers exposed to bituminous materials.

While not strictly an a priori hypothesis, examination of mortality from malignant melanoma, which was reported among workers at the CalTRANS headquarters building in a previous incidence study [Austin, 1985], was also preplanned.

METHODS

Study Site

The California Department of Transportation oversees the maintenance of approximately 26,000 miles of primary and secondary roadways, and, in 1985, employed approximately 15,000 permanent workers [Smith, 1986].

The workforce is currently organized into 17 divisions, 11 geographic districts, and a headquarters. The districts vary in *size* from 350 to 3,500 workers, Los Angeles and San Francisco districts being the largest. The Maintenance Division employs 6,000 workers whose activities have been typical of highway maintenance operations (Table I). The Construction and Engineering Division employs approximately 2,000 workers, mostly engineers who inspect the work of contractors. CalTRANS contracts out major construction projects. Approximately 500 workers are employed in equip-

TABLE I. Hazardous Materials and Exposures in Highway Maintenance and Construction*

Hazard	Operations	Known and suspected health effects
Asbestos	Brake and clutch repair	Asbestosis, lung cancer, mesothelioma
Asphalt	Paving, crack and joint filling, surface sealing, PCC base repair	Burns, dermatitis, photosensitization, lung cancer
Biologic agents	Landscaping, roadside clean-up	Dermatitis, infectious disease, enteric illness, animal/insect bites, *Rhus*, sp.
Carbon monoxide	Toll booths/heavy equipment	Carboxyhemoglobin hypoxia
Coal tar	Surface sealing	Cancers at various sites
Diesel exhaust	Heavy equipment/toll booths	Lung cancer and cancers at other sites
Dusts	Power sweeping, abrasive blasting, chipping, pavement grinding	Respiratory irritation, silica exposure
Electrical hazards (PCB)	Installation of lighting	Electrocution, lymphopoietic cancers
Hydrogen sulfide	Asphalt patching	Respiratory irritation
Lead	Toll booth traffic	Neurobehavioral effects
Moving motor vehicle traffic	Traffic control, construction zone work	Trauma
Noise	Heavy equipment	Hearing loss
Pesticides	Weed control, plant disease and pest management, inhibitor spraying, highway spill clean-up	Lymphopoietic cancers, dermatitis
Portland cement	Paving, bridge repair	Dermatitis, stomach cancer
Solvents (toluene, xylene, TCE, TCA, kerosene, benzene, naphtha, gasoline)	Materials testing, striping, highway spills, bridge painting, sign maintenance, vehicle repair, degreasing, concrete curing	CNS depression, leukemia (benzene), dermatitis
UV/solar radiation	Sun/outdoor work	Skin cancer, melanoma (?), heat stroke
Welding fumes	Fence repair, bridge maintenance, guardrail and median barrier repair, vehicle and sign maintenance	Lung cancer

*NIOSH [1978]; Institute of Transportation Studies [1984]; Key et al [1978]; CalTRANS [1985].

ment shops, where major vehicle repair and outfitting is done. Routine and minor maintenance of vehicles is done at the approximately 400 maintenance stations. Other work sites include 2 warehouses employing 30 to 40 workers, laboratories for analysis of soils, metals, and asphalt, and a headquarters building where approximately 3,500 administrative and clerical workers are employed.

Study Population

The study population was defined as all CalTRANS employees who left employment for any reason between 1970 and 1983 (inclusive) and who died in California between January 1, 1970, and December 31, 1983. There was no minimum employment duration for inclusion in the study population, which included workers who died while active, retired, quit, or were fired, laid off, or otherwise terminated. The study population included all CalTRANS employees: maintenance workers, materials laboratory technicians, engineers, administrators, office workers, secretaries, etc.

Candidates for study were identified from a cumulative, computerized personnel file known as the separation file. This file listed the name, social security number, birth date, sex, ethnicity, and employment data at separation of former CalTRANS employees who left employment since 1970. The separation file was the sole source for ascertaining potential deaths. Pension records and employee records at the district level were not available.

Vital status of 27,162 individuals in the separation file was determined by computerized linkage using the social security number as the match key to an automated form of the State of California death certificate registry [Arellano et al, 1984]. The linkage yielded 1,653 social security number matches, 1,545 of which were exact in last name and sex. The other 108 matches were visually scanned for name, sex, race, and date of death, and 25 were judged with confidence to be true matches. The total number of deaths for analyses was 1,570. Out-of-state deaths were not ascertained. We have no reason to believe that persons dying out of state would have different mortality patterns from those dying in state.

Death Certificate Information

The underlying cause of death listed on the death certificate was coded by nosologists at the California Department of Health Services according to the revision of the International Classification of Diseases (ICD) in effect at the time of death. Deaths spanned the ICD 8th (1968–1978) and 9th (1979–present) revisions. Causes of death of interest in this study that were affected by differences in the 8th and 9th ICD revisions include leukemia, whose ICD codes in the 9th revision (204–208) were expanded from those of the 8th (204–207).

Occupational information

The source of occupational information was also the separation file. The following information was available: district, last job classification, date of separation, and reason for separation (including retirement or death). Because year of hire was not coded, latency or duration effects could not be investigated. Subgroup analyses were carried out for retiree deaths and decedents with a last job classification of highway maintenance and landscape maintenance. Eligibility for retirement was at least 5 years of service and 50 years of age throughout the study period. According to CalTRANS

officials, landscape maintenance workers had the greatest potential for pesticide exposure, and highway maintenance workers had the greatest potential for exposure to chemical hazards in pavement and roadside maintenance. Industrial hygiene data of chemical exposures have not been routinely collected.

Statistical Analyses

Standardized proportional mortality ratios (PMRs) and proportional cancer mortality ratios (PCMRs) were calculated using the Monson [1974] program as adapted by Maizlish [1986], and reference proportional mortalities for the U.S. population through 1980. The PMR program calculated expected number of deaths for up to 57 causes based on the proportions of all deaths in the reference population and the distribution of deaths in the study population in strata of age at death, sex, race, and year of death. Similarly, the PCMR program calculated expected number of deaths for up to 25 cancer causes based on the proportions of cancer deaths in the reference population.

The PMR or PCMR is the ratio of observed deaths to the expected deaths, multiplied by 100. A PMR greater than 100 indicates greater than expected mortality, while a PMR of less than 100 indicates a deficit in mortality. The Poisson distribution was used to assess statistical significance and to compute 95% confidence intervals.

RESULTS

Characteristics of the Study Population

The 1,570 decedents were mostly male (88%) and white (90%) (Table II). Hispanic decedents represented approximately 3% of whites. Approximately 50% of 118 nonwhite males were black, and 28% were Oriental. Mean age at death was 57 for white males and females and 50 for black males. Resignations accounted for approximately two-thirds of all separations, retirement accounted for 12%, and deaths accounted for 16%.

Standardized Proportional Mortality

White males. Statistically significant excess mortality due to all malignant neoplasms (PMR = 118), benign neoplasms (PMR = 343), and external causes (PMR = 122) was observed among 1,260 white males (Table III). Lymphopoietic cancers (PMR = 157) and cancers of the digestive organs (PMR = 128), skin (PMR = 218), and brain (PMR = 162) contributed to the overall cancer excess (Table IV). Nonsignificant elevations in cancer of the large intestine (PMR = 143) and stomach cancer (PMR = 145) accounted for most of the excess cancer of the digestive organs. Of the 14 skin cancers, 11 were malignant melanoma. Lymphosarcomas and reticulosarcomas (PMR = 219) and leukemia (PMR = 162) accounted for most of the excess lymphopoietic cancer excess. More deaths than expected were also observed for testicular cancer (PMR = 217), although this was not statistically significant. Ten of the 12 benign neoplasms were brain tumors. Suicides (PMR = 154) and accidents (PMR = 120), particularly motor vehicle accidents (PMR = 141), were mainly responsible for the overall excess in deaths due to external causes (Table III).

Three soft tissue sarcomas (ICD 171) were observed versus 1.6 expected. One cancer of the pleura (ICD 163.9) was observed. There was a significant deficit in

TABLE II. Demographic and Occupational Characteristics, Separated CalTRANS Employees, 1970–1983

Item	N	%
Total deaths	1570	100
Males	1378	88
White[a]	1260	80
Black	66	4
Oriental[b]	39	1
Other		
Females	192	12
White[c]	168	10
Black	10	1
Oriental	11	—
Other	3	
Separation category		
Resignations/terminations	1070	69
Retirement	194	13
Death	258	16
Other	48	2
Last job classification		
Landscape maintenance	106	7
Highway maintenance[d]	327	21
Laboratory workers, inspectors, engineers, administrators, and other office workers	1137	72

[a]Includes 47 Hispanic decedents.
[b]Includes Chinese, Japanese, Korean, and Vietnamese.
[c]Includes 3 Hispanic decedents.
[d]Includes highway maintenance, heavy equipment operators, and supervisors.

deaths due to all circulatory diseases (PMR = 88) and symptoms, senility and ill-defined conditions (PMR = 12) (Table III).

Nonwhite males. Black males (N = 66) experienced nonsignificant excess deaths due to digestive organ cancers [PMR = 7/3.67 = 191; CI(95%) = 77,3941 and arteriosclerotic heart disease (PMR = 143) (Table III). Three leukemias were observed among 33 Oriental males (Chinese, Japanese, Korean, or Vietnamese). Based on crude (age unadjusted) U.S. proportional mortalities for Chinese and Japanese males in 1980, only 0.27 deaths would be expected (PMR = 1091, $p < .01$).

Females. Excess deaths due to all malignant neoplasms (PMR = 125) and suicides (PMR = 215) were found among 168 white females (Table III). A significant excess of lung cancer (17/9.0, PMR = 189) contributed to most of the cancer excess. Nonsignificant deficits in circulatory disease mortality (PMR = 79) were also observed. Among 10 black females, proportional mortality from external causes was elevated (PMR = 203, 95% CI: 65,475).

White male retirees. Among 160 white male retirees, significant excess deaths were found for all malignant neoplasms (PMR = 152) and nonsignificant excesses for cirrhosis of the liver (PMR = 195) (Table V). A significant deficit in proportional mortality was found for arteriosclerotic heart disease (PMR = 67). Significant excess cancers of the digestive organs (PMR = 182)—mainly cancer of the large intestine

TABLE III. Standardized Proportional Mortality Ratios, Cal' RANS, 1970-1983

Cause of death	White ma--			Black males			White females		
	Obs.	PMR	95N CI[a]	Obs.	PMR	95% CI	Obs.	PMR	95% CI
Total deaths	1260			66			168		
All malignant neoplasms	341	118[b]	106,131	16	123	70,200	71[c]	125	98,158
Benign neoplasms	12	343[b]	177,597	0	0	—	1	123	12,691
Allergic, endocrine, metabolic diseases	23	107	68,151	0	0	—	4	80	20,204
All diseases of the nervous system	13	102	54,174	0	0	—	3	121	24,353
All circulatory disease	495	88[b]	80, 96	29	122	82,175	48	79	59,104
Arteriosclerotic heart disease	375	93	84,103	18	143	85,226	23	67	42,100
All respiratory diseases	57	82	61,106	2	60	6,187	4	49	19,126
All diseases of the digestive system	69	105	82,132	3	78	26,231	11	121	61,216
Cirrhosis of liver	52	127	94,168	3	124	25,362	7	143	57,295
All external causes	218	122[b]	109,139	13	94	50,161	21	132	81,202
All accidents	134	120[d]	101,143	7	111	45,229	10	105	50,193
Motor vehicle accidents	83	141[b]	113,175	5	178	57,415	5	89	39,200
Suicides	64	154[b]	118,197	2	197	20,706	9	215	99,395

[a]CI = Poisson confidence intervals.
[b]$p < .01$ Poisson two-tailed test.
[c]White female lung cancer PMR: 17/9.0 = 189 (95% CI = 110,302), $p < .05$.
[d]$p < .05$ Poisson two-tailed test.

TABLE IV. Standardized Proportional Mortality Ratios (PMRs) for Cancers and Standardized Proportional Cancer Mortality Ratios (PCMRs) in CalTRANS White Males, 1970–1983

Cause of death	Obs.	Exp.	PMR	95% CI[a]	PCMR
Total cancer deaths	341	289.27	118[b]	106,131	100
Cancer of buccal cavity	8	8.88	90	39,177	78
Cancer of the digestive organs	90	70.14	128[c]	103,157	108
Cancer of the esophagus	9	7.02	128	59,243	109
Cancer of the stomach	15	10.35	145	81,239	123
Cancer of large intestine	35	24.52	143	99,199	120
Cancer of rectum	8	6.50	123	53,242	104
All cancer of liver	4	4.93	81	31,215	68
Cancer of pancreas	19	14.81	128	77,200	109
All cancer of lung	105	107.60	98	80,119	83
Cancer of skin	14	6.42	218[c]	119,366	193[c]
Cancer of soft tissues	3	1.55	194	40,587	—
Cancer of prostate	18	13.92	129	76,204	103
Cancer of testis	4	1.84	217	84,563	188
Cancer of bladder	9	6.50	138	63,272	114
Cancer of kidney	10	7.55	132	64,273	114
Cancer of brain and other CNS	16	9.88	162	93,263	143
All lymphopoietic cancer	44	28.05	157[b]	115,210	135
Lymphosarcoma and reticulosarcoma	11	5.03	219[c]	110,392	191
Leukemia and aleukemia	18	11.10	162	96,256	158

[a]CI = Poisson confidence intervals.
[b]$p < .01$ Poisson two-tailed test.
[c]$p < .05$ Poisson two-tailed test.

(PMR = 245), skin (PMR = 738), brain (PMR = 556), and all lymphopoietic tissue (PMR = 227)—contributed to the overall excess cancer mortality.

Landscape and highway maintenance. Cancer mortality among white males with a last job of landscape maintenance was unremarkable (Table VI). Landscape maintenance workers experienced a nonsignificant excess of deaths due to cirrhosis of the liver (PMR = 229) and motor vehicle accidents (PMR = 170). Among highway maintenance workers (Table VI), there was a significant excess of deaths from emphysema (PMR = 250) and all accidents (PMR = 169), including motor vehicle accidents (PMR = 196). There was a nonsignificant elevation of deaths from cancer of the digestive organs (PMR = 151)—primarily cancer of the stomach (PMR = 247) and prostate cancer (N = 226). A significant deficit of deaths due to circulatory disease (PMR = 83) was also observed.

Standardized Proportional Cancer Mortality

Among white males a significantly elevated PCMR was found for skin cancer (PCMR = 193) (Table IV). Proportional cancer mortality due to lung cancer was significantly less than expected (PCMR = 83). Greater than expected numbers were observed for leukemia (18 vs. 12.9), lymphosarcomas and reticulosarcoma (11 vs. 5.7), digestive organ cancer (90 vs. 83.1), and brain cancer (16 vs. 11.1). Among white females, there was a nonsignificant excess of proportional cancer mortality due to respiratory system cancers (PCMR = 152) and a nonsignificant deficit due to digestive organ cancers (PCMR = 52).

TABLE V. Standardized Proportional Mortality Ratios in CalTRANS White Males, 1970–1983, Retired at Separation*

Cause of death	Obs.	Exp.	PMR	95% CI[a]
Total deaths	160			
All malignant neoplasms	65	42.74	152'	117,194
Cancer of the digestive organs	19	10.46	182[b]	110,284
Cancer of stomach	3	1.47	204	68,614
Cancer of large intestine	9	3.67	245[b]	112,465
Cancer of rectum	3	.90	333	67,978
All cancer of lung	18	16.97	106	63,167
Cancer of skin	6	.81	738[c]	270,1608
Cancer of brain and other CNS	7	1.26	556[c]	223,1146
All lymphopoietic cancer	8	3.53	227	98,447
Lymphosarcoma and reticulosarcoma	3	.58	514[b]	103,1517
Cancer of other lymphatic tissue	4	1.32	302	76,773
Benign neoplasms	2	.46	433	43,1565
All circulatory disease	54	76.58	71'	53, 91
Arteriosclerotic heart disease	36	53.81	67'	41, 93
All respiratory diseases	10	9.58	104	50,191
All diseases of the digestive system	12	8.29	145	75,253
Cirrhosis of liver	10	5.14	195	94,358
All external causes	10	11.58	86	41,158

*CalTRANS service and disability retirements.
[a]CI = Poisson confidence intervals.
[b]$p < .05$ Poisson two-tailed test.
[c]$p < .01$ Poisson two-tailed test.

DISCUSSION

The major findings were excess mortality from neoplasms (malignant and benign), accidents, and suicides. Exposure data were not sufficient to associate the apparent risks with specific job hazards, job classifications, job duration, or time since first exposure. Nonetheless, the pattern of mortality was consistent, in part, with previously hypothesized effects, and plausibly related to known occupational hazards and suspect agents. Before discussing the possible etiologic significance of these findings, methodologic limitations must be addressed.

Limitations

PMR methodology. The proportional mortality ratio is not a direct measure of absolute risk for a cause of death. The PMR study design has been criticized for nonindependence of cause-specific results; i.e., risk estimates for specific causes may be overstated if PMRs for other causes are low. This may occur if there are selection effects related to hiring practices (i.e., healthy worker effect). Empirical evidence suggests, however, that PMRs are frequently accurate representations of the mortality experience [Beaumont et al, 1981; St. Claire and Butler, 1981; Roman et al, 19831. PMR analyses have also been criticized for selective ascertainment of deaths. In the present study, ascertainment of California deaths was highly complete. Errors in record linkage using the California Automated Mortality Linkage System (CAMLIS) are small; 4–6% of matches have been found to be false-positive or false-negative [Arellano, 1985]. Out-of-state deaths were not ascertained, but this would not be expected to substantively alter the findings. We have no specific data to prove or

TABLE VI. Standardized Proportional Mortality Ratios in CalTRANS White Males, 1970–1983, Highway Maintenance Classifications at Separation

	Highway maintenance			Landscape maintenance		
Cause of death	Obs.	PMR	95% CI+[a]	Obs.	PMR	95% CI+
Total deaths	307			87		
All malignant neoplasms	81	117	93,146	16	86	49,140
Cancer of the digestive organs	25	151	97,223	3	67	13,197
Cancer of stomach	6	227	83,495	0	0	—
All cancer of lung	25	98	63,145	4	60	15,153
Cancer of skin	2	122	12,439	1	212	—
Cancer of prostate	7	226	91,466	1	110	—
Cancer of brain and other CNS	4	160	40,410	1	142	—
All lymphopoietic cancer	8	115	50,226	1	50	—
Benign neoplasms	3	345	69,1011	0	0	—
All circulatory disease	110	83[b]	68, 99	33	92	63,130
All respiratory diseases	15	93	52,153	6	131	48,285
Emphysema	8	250[b]	108,492	1	109	—
All diseases of the digestive system	15	92	51,152	8	187	80,368
Cirrhosis of liver	13	127	68,217	6	229	84,498
All external causes	73	145[c]	114,182	23	135	85,203
All accidents	53	169[c]	127,222	14	162	89,272
Motor vehicle accidents	33	196[c]	134,276	10	170	82,313
Suicides	16	139	79,226	6	157	58,342

[a]CI+ = Poisson coefficient intervals.
[b]$p < .05$ Poisson two-tailed test.
[c]$p < .01$.

refute the notion that the frequency of cause-specific out-migration of CalTRANS workers is different from other California residents. California is widely recognized as a desirable state for retirement, and this may minimize potential biases due to out-migration.

Multiple comparisons. Multiple comparisons were unavoidable in screening many causes of death, and some findings may be due to chance. Nonetheless, excess lymphopoietic cancers and digestive organ cancers were hypothesized effects, and excess malignant melanoma mortality was confirmed.

Confounding biases. Adjustments using indirect standardization were made for age at death, sex, race, and year of death. Other determinants of mortality, including socioeconomic status (SES), state of residence, cigarette smoking, and alcohol consumption were not controlled. Cancer of the colon, lymphopoietic tissue, melanoma, and brain cancer are associated with increasing social class [Milham, 1985; Berg and Howell, 1975; Levin et al, 19791. Because higher SES occupations such as engineers, administrators, and other professionals were a large part of the study population, uncontrolled SES may be responsible for part of the elevated mortality. However, as Milham [1985] pointed out, controlling for SES presents difficulties because SES, occupation, and potential exposures may not be independent risk factors.

Based on comparisons of age-adjusted mortality rates (per 100,000) for white males, 1970–1979, geographic variations in mortality between the U.S. and California are unlikely to account for observed excesses of colon cancer (U.S., 20.0; California, 18.8), leukemia (U.S., 9.1; California, 9.2), or melanoma (U.S., 2.4; California,

2.9) [EPA/NCI, 1983]. Except for lung cancer and emphysema, cigarette smoking is not strongly implicated in the types of cancer deaths observed in excess among males in this study [Surgeon General, 1982]. Excessive alcohol consumption is associated with suicides, cirrhosis of the liver, and fatal motor vehicle accidents [Berkelman et al, 1986; Baker et al, 1984]. Data on cigarette or alcohol consumption were not available for the study group.

Misclassification errors. Misclassification of underlying cause of death on death certificates is not a likely explanation of findings for colorectal cancer, melanoma, lymphopoietic cancers, or cancers of the stomach, lung, or brain. These cancers generally have greater than 90% detection rates in comparisons of death certificates and hospital records. However, soft-tissue cancers are seriously underreported on death certificates, and this could mask greater proportional mortality for this cause [Percy et al, 1981].

An important limitation of this study was the lack of exposure data, work histories, knowledge of previous or concomitant non-CalTRANS employment and recreational activities involving hazardous substances, and data on nonoccupational risk factors. Exposure classification based on last-job classification may have misclassified exposure, depending on the degree of job mobility, which was not known.

Lack of hire date precluded investigation of duration or latency effects. However, the subgroup of white male retirees experienced greater proportional mortality at various cancer sites than all white males. This is consistent with a dose-duration effect, because retirees had at least 5 years of employment. Because most cancers have 10–30 year latency periods, the exposures of etiologic significance may have occurred during the 1950s and 1960s. Current work practices or materials may be substantively different. However, latencies for leukemia may be as short as 5–10 years, so recent exposures may be relevant.

Etiologic Significance

There have been few previous mortality studies of state highway maintenance workers, or workers exposed to the same chemical and physical hazards under similar conditions. Mortality studies of white male workers, involved in excavating, grading, paving, road machinery operaton and highway maintenance in Minnesota [Bender and Parker, 1987], Washington [Milham, 1983] and California in 1960 [Petersen and Milham, 1980] confirm excess mortality from accidental causes among white males, including motor vehicle accidents. Excess leukemia mortality (SMR = 420) was found among Minnesota highway maintenance workers with 30–39 years of service. Primary malignant neoplasms of the lung were elevated (PMR = 119) in Washington road workers, but not in California (PMR = 92) [Petersen and Milham, 1980], or Minnesota (SMR = 70). Excess prostate cancers were found in workers from Washington (PMR = 155, ages 20–@), and an elevated brain cancer risk (SMR = 294) was reported among Canadian highway and bridge maintenance workers [Howe and Lindsay, 1983].

Kovasznay [1984] studied 362 New York State highway sprayers exposed to 2,4,5-T and 2,4-D and a comparison group of age-matched, nonexposed motor vehicle registrants. A small, nonsignificant excess of cancers was reported, but the number of cancer cases was small, follow-up was short, and other maintenance workers were not included. In a survey of 15 state highway commissions or boards of health, Baylor and Weaver [1968] did not report serious health effects associated

with exposure to asphalt in highway construction. However, neither death certificates nor medical records were reviewed by the authors. Possible health effects may be suggested from studies of other workers exposed to the same materials, albeit under different conditions.

Lymphopoietic cancer. Excess lymphopoietic cancers were found among both white and Oriental males (Table IV). Excess mortality from leukemia has been found among workers with exposure to benzene [IARC, 19821 and possibly other solvents, and among agricultural workers with potential exposures to solvents, pesticides, and viruses, and a subgroup of Minnesota highway workers [Bender and Parker, 19871.

Painters, highway line stripers, technicians in materials testing laboratories, asphalt workers, motor vehicle maintenance workers, and other CalTRANS employees are potentially exposed to solvents. Exposure may occur in asphalt operations using cutback asphalts, in which solvents (usually naphtha or other petroleum distillate) blended with asphalt cement evaporate during curing [Asphalt Institute, 19821. Another important exposure may occur when organic solvents, including gasoline, are used for cleaning bitumin contamination from skin [Burgess, 19811. This may also have the effect of solubilizing asphalt in a manner analogous to skin painting. Laboratory testing for asphalts used in highway or street construction have historically relied on benzene. Benzene, carbon disulfide, carbon tetrachloride, and trichloroethylene are currently recommended for laboratory testing of asphalt [ASTM, 1984; AASHTO, 19821. At CalTRANS, asphalt testing for certification of contractors' work requires the use of benzene, trichloroethylene, toluene, xylene, gasoline, naphtha, Stoddard solvent, 1,1,1-trichloroethane,and kerosene [CalTRANS, 19781.

Hazardous-material spills frequently involve fuels, flammables, and other solvents. In California, 8 reportable spills occur on average each week, with one-third of the incidents involving leaks and drops from moving motor vehicles [Shaw et al, 19861. This suggests hazards of potential high-level exposures from large spills and lower-level exposures from contaminated roadway dusts.

The mixing, loading, and application of pesticides, usually from spray trucks, have been **tasks** shared among members of landscape maintenance crews at CalTRANS. Excess mortality from lymphopoietic cancers was not observed among white males with a last job in landscape maintenance. Phenoxyacetic herbicides were reported to have been used prior to **1970.** Since the 1970s, amitrole, triazines, bromocil, cacodylic acid, dichlobenil, dalapon, diquat, diphenamid, diuron, trichlorophenol acetic acid, glyphosate, fosamine ammonium, chlorflurenol, monosodium methylarsonate (MSMA), orazalin, and sodium trichloroacetate (TCA) have been used [CalTRANS, 19811. Since the 1970s, organophosphates and carbamates of relatively low acute toxicity, pyrethrin, bacillus thuriengensis (BT), and petroleum oil, among others, were used as insecticides. Amitrole, glyphosate, and oryzalin are currently considered animal oncogens [USEPA, 1985; **USDHHS** (NTP), 1983].

Skin cancer. Skin cancers, mostly melanoma, were significantly elevated in white males (Table IV) and retirees (Table V). Climatic conditions in California favor year-round outdoor highway maintenance work. Consequently, exposure to solar radiation may occur more frequently than in many other states, and this may explain, in part, excess melanoma in the study group. It has been suggested that cumulative exposure to ultraviolet (UV) radiation is associated with nonmelanoma skin cancers, while blistering overdoses are more closely associated with melanoma [Page and Asire, 19851. Occupational risk factors of nonmelanoma skin cancer include exposure

to UV radiation or sunlight [Birmingham, 19781, X-radiation, arsenic, and coal tar pitch [NIOSH, 1977b].

Cancer of digestive organs. Colon and stomach cancers were elevated among white and black males (Table IV). Minnesota highway maintenance workers with long latencies experienced an excess of intestinal cancers (SMR = 580). Recent studies have identified elevated risks of digestive organ cancer among asbestos workers [Goldsmith, 19821, roofers exposed to coal tar pitch volatiles [Hammond et al, 1976; Silverstein et al, 1985a], cement workers [McDowall, 19841, chemists [Hoar and Pell, 19811, rubber workers [Monson and Nakano, 1974; McMichael et al, 19741, non–coke-oven steel workers [Redmond et al, 19811, workers exposed to oil mists and abrasive grinding [Jarvholm et al, 1981; Decouflé, 1978; Park et al, 1984; Silverstein et al, 1985b], pattern/model makers in the automobile industry [Swanson and Belle, 19821, and workers with sedentary jobs [Garabrant et al, 1984; Gerhardsson et al, 1986; Vena et al, 19851.

Relevant exposures among CalTRANS workers included asbestos, asphalt fumes or coal tar pitch volatiles containing polyaromatic hydrocarbons, cement and other abrasive dusts, and sedentary jobs. The pattern of excess stomach cancer without a concomitant increase in lung cancer among highway maintenance workers (Tables III and VI) has been observed in cement workers, but not in workers exposed to asbestos or coal tar pitch volatiles. *An* excess of colon cancers is also consistent with sedentary work or uncontrolled socioeconomic status among professionals, whose colon cancer risk is higher than other workers, and who made up a large percentage of the study group.

Nonoccupational factors in the epidemiology of digestive organ cancers have received considerable attention. There is much speculation that dietary factors involving fat, meat, and fiber consumption influence national differences [Schottenfeld and Winawer, 19821.

Lung cancer. Excess lung cancers were observed among white females in PMR and PCMR analyses. Historically, females have been underrepresented in maintenance jobs, and it is not likely that exposures in maintenance work were responsible for the observed excess. Most female decedents were office workers, and exposures in the office environment, including cigarette smoke and asbestos [Cal-OSHA, 19801, may be explanatory.

The absence of lung cancer excesses in males does not, without qualification, support a role for inhalation exposures to asphalt fumes or coal tar pitch volatiles. However, if dermal or other routes of exposure affecting other sites were etiologic, expected lung cancer mortality might be observed. The findings do not preclude excess lung cancers for small groups of males whose risk may have been obscured when included in larger groups. A deficit in lung cancer mortality was also observed in Minnesota highway maintenance workers (SMR = 70).

Fatal accidents. Excess mortality from motor vehicle accidents was found among white males (Table III). Road vehicles account for approximately one-third of work-related injury deaths in the **U.S.** [Baker et al, 19841. Excess mortality due to fatal accidents, particularly motor vehicle accidents, is not surprising in a population of workers exposed to vehicular traffic and heavy equipment. According to CalTRANS officials, motorists currently break through construction barriers on average 5 times per day. Of 98 fatal motor vehicle accidents, **54%** were due to a collision with a stopped vehicle or pedestrian on a highway, and **60%** separated on the same

date as death, indicating a death during active status. However, because time of day and day of week were not available in our analysis, the work-relatedness of fatal accidents is not precisely known.

Other Findings. White males and females experienced excess suicides (Table III). Unidentified pyschosocial stressors on and off the job may be implicated. The finding of excess cirrhosis deaths among white male retirees (Table V) also suggests a role for excess alcohol consumption, or interactions or misdiagnoses regarding solvents. Arteriosclerotic heart disease among black males, brain cancers and benign neoplasms in white males (nearly all of which were brain tumors), and emphysema and prostate cancer among highway maintenance workers were not hypothesized effects and require confirmation in future studies.

CONCLUSIONS AND RECOMMENDATIONS

Associations between specific causes of death and employment at the California Department of Transportation have been observed. It is unlikely that the pattern of multisite cancer mortality and fatal accidents could have all arisen by chance, but methodologic limitations and uncontrolled potentially confounding factors may be partly responsible for the associations. Cancer of the digestive organs, lymphopoietic cancers, skin cancers, and motor vehicle accidents are all plausibly related to recognized hazards of highway maintenance work, but also to nonoccupational factors. Further epidemiologic investigations are necessary to confirm the apparent excess mortality and to quantify occupational and nonoccupational risk factors and their interactions. State, county, and municipal departments of transportation and the highway and street construction industry are encouraged to evaluate current work practices and materials and to take precautionary steps to reduce hazards.

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