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Proportionate Mortality Ratio Analysis of Automobile Mechanics and Gasoline Service Station Workers in New Hampshire

Eugene Schwartz, MD, MPH

A proportionate mortality ratio (PMR) analysis of all deaths recorded from 1975 to 1985 among New Hampshire white male residents (age 20 years or older) was performed using death certificate information. Among automobile mechanics, the analysis revealed increases in mortality from leukemia (PMR = 178, N = 6); cancers of the oral cavity (PMR = 163, N = 4), lung (PMR = 112, N = 36), bladder (PMR = 169, N = 5), rectum (PMR = 182, N = 4), and lymphatic tissues (PMR = 200, N = 6); and cirrhosis of the liver (PMR = 140, N = 13) and suicide (PMR = 177, N = 22; $p < 0.05$). Workers in the gasoline service station industry experienced a leukemia mortality excess (PMR = 328, N = 3; $p < 0.05$) as well as increases in deaths from suicide (PMR = 162, N = 4), emphysema (PMR = 245, N = 4), and mental and psychoneurotic conditions (PMR = 394, N = 3). These workers are potentially exposed to a variety of substances including gasoline vapor, benzene, solvents, lubricating oils and greases, and asbestos (from brake and clutch repair) as well as welding fumes and car and truck exhaust. Despite limitations regarding the small number of deaths and methodologic constraints, the results of this analysis suggest that one or more of the exposures experienced by these workers poses a significant carcinogenic risk. More definitive epidemiologic studies are required to determine if the leukemia excess is associated with exposure to benzene, gasoline, or other workplace substances.

Key words: occupationally related leukemia mortality, benzene exposure, solvent exposure

INTRODUCTION

An estimated 1.5 million workers were employed in the automobile repair and gasoline service station industry during 1985 in the United States [Bureau of Labor Statistics, 1986]. Tradesmen in this industry provide a variety of services in gasoline stations as well as in brake, muffler, ignition, glass, body, and paint shops. Potential exposures include gasoline vapor, benzene, solvents, lubricating oils and greases, asbestos (from brake and clutch repair), fiberglass, epoxies, and adhesives as well as welding fumes and car and truck exhaust. As in many service-oriented industries,

Bureau of Disease Control, Department of Public Health Services, New Hampshire Department of Health and Human Services, Concord.
Address reprint requests to Dr. Eugene Schwartz, State Epidemiologist, New Hampshire Department of Health and Human Services, Division of Public Health Services, Bureau of Disease Control, 6 Hazen Drive, Concord, NH 03301.
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epidemiologic investigations of these trades are particularly difficult to perform because workers are employed in small shops and generally are not unionized nor subject to any form of centralized personnel record-keeping requirements.

Among the diverse group of workers in this industry, automobile mechanics and gasoline station workers often labor together in small shops, have shared responsibilities, and experience similar workplace exposures. Our knowledge of the mortality experience of these workers stems from the incidental findings of population-based proportionate mortality ratio (PMR) studies and case reports. These studies have revealed excesses of leukemia; cancers of the buccal cavity, esophagus, lung, bladder, testis, and kidney; nonmalignant respiratory disease; duodenal ulcers; multiple sclerosis; aplastic anemia; homicide; suicide; and injuries among automobile mechanics and gasoline service station workers, although these findings have by no means been consistent.

Milham's [1983] study in Washington State revealed a mildly elevated PMR for leukemia among auto mechanics (PMR = 118, N = 34) as well as increases in the proportion of deaths from esophageal (PMR = 163, N = 22) and bladder cancer (PMR = 119, N = 28), nonmalignant respiratory disease (PMR = 123, N = 255), multiple sclerosis (PMR = 177, N = 14), and fires or explosions (PMR = 143, N = 20). Among gas station/garage owners and attendants, PMR elevations were found for cancers of the buccal cavity (PMR = 144, N = 8), kidney (PMR = 122, N = 15), bladder (PMR = 144, N = 26), and testis (PMR = 161, N = 7); duodenal ulcers (PMR = 194, N = 20); and aplastic anemia (PMR = 254, N = 4).

Based on small numbers of deaths, Dubrow and Wegman [1984] found a mild PMR elevation for leukemia among auto mechanics and gas station attendants in Massachusetts (PMR = 123 and 127, respectively). Peterson and Milham [1980] reported statistically significant PMR elevations for esophageal cancer (PMR = 232, N = 18), nonmalignant respiratory disease (PMR = 129, N = 118), and motor vehicle injuries (PMR = 124, N = 97) as well as an increase in the proportion of deaths from homicide (PMR = 152, N = 16) among auto repairmen in California. Significant elevations in lung cancer (PMR = 162, N = 24) and cirrhosis of the liver (PMR = 163, N = 32) as well as increases in cancers of the buccal cavity (PMR = 186, N = 6) and testis (PMR = 278, N = 4) and homicide (PMR = 179, N = 12) were observed among California auto service and gas station workers. Guralnick [1963] reported statistically significant elevations of lung cancer (PMR = 128, N = 119) and injury-related deaths (PMR = 107, N = 610) as well as increases in the proportion of deaths from buccal cavity cancer (PMR = 159, N = 27) and suicide (PMR = 113, N = 157) among auto mechanics in her national survey. The pattern of mortality among auto service and parking attendants was unremarkable in that study. Finally, the Registrar General [1979] reported higher than expected lung cancer rates among motor mechanics and auto engineers in England and Wales. In addition, a higher than expected total mortality and a high cancer mortality rate were reported for garage proprietors. This paper reports the patterns of mortality among automobile mechanics and workers in the gasoline service station industry as determined by a state-wide, population-based analysis of death certificates in New Hampshire [Schwartz and Grady, 1986].

MATERIALS AND METHODS

A PMR analysis was performed for all deaths occurring between 1975 and 1985 among white male residents (age 20 years or older) in New Hampshire (N = 37,426).

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Occupation, industry, age, date, and cause of death information was abstracted from death certificates. The underlying cause of death was categorized according to the Eighth Revision of the International Classification of Diseases and coded by a trained nosologist at the New Hampshire Bureau of Vital and Health Statistics [U.S. DHEW, 1968]. Occupation and industry data were classified into one of 503 occupational and 231 industrial categories according to the Industry and Occupation Classification devised by the U.S. Bureau of the Census [1982]. The analysis was performed by utilizing a computer program developed by Monson [1974], which calculates cause-specific expected numbers of deaths based on the mortality experience of the U.S. general population. In this analysis, the proportion of deaths in specific cause of death categories is compared with the corresponding proportion of deaths in the U.S. population. The PMRs are standardized for the potentially confounding effects of age, sex, race, and year of death.

In addition, standardized mortality odds ratios (SMORs) were derived by calculating the ratio of mortality odds for selected causes of death using cancer deaths as controls. The SMOR is calculated in the same manner as the relative odds in case-control studies and provides a better estimate of the relative risk than the PMR [Miettinen and Wang, 1981]. Statistically significant differences between observed and expected deaths and confidence intervals were determined by utilizing a summary Mantel-Haenszel χ^2 test with 1 df.

RESULTS

Among the total population of decedents were 453 automobile mechanics (occupational code 505) and 134 who worked in the gasoline service station industry (industrial code 621). The distributions of observed and expected deaths are presented in Tables I and II. Too few deaths were observed in the occupational category for gasoline and services station attendants to perform a meaningful analysis, so the industrial category for the gasoline service station industry was analyzed.

Automobile mechanics revealed a statistically significant PMR elevation for suicide (PMR = 177, N = 22; $p < 0.05$). PMR increases for leukemia (PMR = 178, N = 6); cancers of the oral cavity (PMR = 163, N = 4), lung (PMR = 112, N = 36), bladder (PMR = 169, N = 5), rectum (PMR = 182, N = 4), and lymphatic tissues (PMR = 200, N = 6); and nonmalignant blood dyscrasias (PMR = 182, N = 2) and cirrhosis of the liver (PMR = 140, N = 13) were observed. Based on small numbers of deaths, workers in the gasoline service station industry revealed statistically significant PMR elevations for leukemia (PMR = 328, N = 3; $p < 0.05$) and mental and psychoneurotic and personality disorders (PMR = 394, N = 3; $p < 0.05$). PMR increases were also observed for emphysema (PMR = 245, N = 4) and suicide (PMR = 162, N = 4). The SMORs are virtually identical to the PMRs, confirming the finding of excess leukemia among both groups.

Table III reveals the distribution of leukemia and hematologic deaths delineated by occupation/industry, age, and type. Among the nine leukemia deaths observed, five were myeloid (including one erythroleukemia), two were lymphoid, and two were unspecified. In addition, two deaths from nonmalignant blood disorders among the mechanics included one aplastic anemia and one unspecified anemia. The latter death certificate also noted the diagnosis of "dysmyelopoiesis-preleukemia." Among

TABLE I. Observed and Expected Deaths and PMRs for Automobile Mechanics (Occupational code 505) in New Hampshire, 1975–1985 (Total deaths = 453)

ICD[a]	Cause of death	Obs[b]	Exp[c]	PMR[d]	95% CI LL	95% CI UL	χ^2
140–209	All malignant neoplasms	101	95.8	105	89	125	0.36
140–149	Cancer of buccal cavity and pharnyx	4	2.5	163	62	429	0.99
150–159	Cancer of digestive organs	24	24.2	99	67	146	0.00
150	Esophagus	3	2.1	142	46	437	0.38
151	Stomach	4	3.5	114	43	301	0.06
153	Large intestine	5	9.1	55	23	129	1.90
154	Rectum	4	2.2	182	69	475	1.47
155–156	Liver	2	1.8	111	28	440	0.02
157	Pancreas	4	4.8	84	32	222	0.13
160–163	Cancer of respiratory system	37	33.7	110	81	149	0.36
161	Larynx	1	1.2	84	12	593	0.03
162–163	Lung	36	32.2	112	82	153	0.49
185	Cancer of prostate	8	8.5	95	48	187	0.03
188	Cancer of bladder	5	2.9	169	72	402	1.44
189	Cancer of kidney	1	2.2	45	7	299	0.69
191–192	Cancer of brain and CNS	2	2.6	78	20	309	0.13
200–209	All lymphopoietic cancer	12	9.2	131	75	228	0.89
204–207	Leukemia and aleukemia	6	3.4	178	81	392	2.09
202,203,208,209	Cancer of other lymph tissue	6	3.0	200	91	437	3.02
280–289	Diseases of blood	2	1.1	182	47	713	0.75
290–317	Mental and psychoneurotic disorders	1	3.2	32	5	200	1.49
390–458	Diseases of circulatory system	215	218.4	98	90	108	0.11
460–519	Nonmalignant respiratory disease	27	31.5	86	60	123	0.70
492	Emphysema	4	5.2	77	29	203	0.28
571	Cirrhosis of liver	13	9.3	140	82	238	1.52
950–959	Suicide	22	12.4	177	120	262	8.14[e]
	All other causes of death	72	81.3	89	70	112	.06

[a]International Classification of Disease, 8th Revision.
[b]Obs, observed number of deaths.
[c]Exp, expected number of deaths.
[d]PMR, (Obs/Exp) × 100.
[e]$p < 0.05$.

the seven deaths from malignancies of other lymphatic tissues, four were classified as lymphomas, one as non-Hodgkin lymphoma, and two as multiple myeloma. Of the four deaths caused by mental or psychoneurotic and personality disorders, three were due to alcoholism and one was due to dementia.

Among the 6 automobile mechanics who died of leukemia, occupational statements entered on death certificates included "automechanic" (two), "mechanic" (two), "auto repair" (one), and "mechanic-retired" (one). Similarly, the three leukemia deaths classified as gasoline service station workers included the occupational statements "service station attendant" (one), "manager-retired" (one), and "service station owner" (one). Because occupational histories were not available, analyses by job title, duration of employment, and latency were not possible.

DISCUSSION

State-wide, population-based PMR analyses serve to provide an indication of the status of workplace safety and health conditions and to generate hypotheses

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Exp[c]	PMR[d]	95% CI LL	95% CI UL	χ^2
95.8	105	89	125	0.36
2.5	163	62	429	0.99
24.2	99	67	146	0.00
2.1	142	46	437	0.38
3.5	114	43	301	0.06
9.1	55	23	129	1.90
2.2	182	69	475	1.47
1.8	111	28	440	0.02
4.8	84	32	222	0.13
33.7	110	81	149	0.36
1.2	84	12	593	0.03
32.2	112	82	153	0.49
8.5	95	48	187	0.03
2.9	169	72	402	1.44
2.2	45	7	299	0.69
2.6	78	20	309	0.13
9.2	131	75	228	0.89
3.4	178	81	392	2.09
3.0	200	91	437	3.02
1.1	182	47	713	0.75
3.2	32	5	200	1.49
18.	98	90	108	0.11
11.5	86	60	123	0.70
5.2	77	29	203	0.28
9.3	140	82	238	1.52
2.4	177	120	262	8.14[e]
1.3	89	70	112	.06

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TABLE II. Observed and Expected Deaths and PMRs for Gasoline Service Station Industry (Industrial code 621) in New Hampshire, 1975–1985 (Total deaths = 134)

ICD[a]	Cause of death	Obs[b]	Exp[c]	PMR[d]	95% CI LL	95% CI UL	χ^2
140–209	All malignant neoplasms	27	28.0	96	69	134	0.05
140–149	Cancer of buccal cavity and pharynx	0	0.7	0	0	0	0
150–159	Cancer of digestive organs	9	7.2	126	67	236	0.50
150	Esophagus	2	0.6	322	87	1188	3.07
151	Stomach	1	1.0	96	14	675	0.00
153	Large intestine	3	2.7	111	36	340	0.03
154	Rectum	1	0.7	152	22	1061	0.18
155–156	Liver	0	0.5	0	0	0	0
157	Pancreas	1	1.4	70	10	488	0.13
160–163	Cancer of respiratory system	7	10.1	69	34	140	1.04
161	Larynx	0	0.4	0	0	0	0
162–163	Lung	7	9.7	73	36	147	0.80
185	Cancer of prostate	3	2.5	119	39	364	0.10
188	Cancer of bladder	1	0.9	112	16	790	0.01
189	Cancer of kidney	1	0.7	152	22	1057	0.18
191–192	Cancer of brain and CNS	0	0.7	0	0	0	0
200–209	All lymphopoietic cancer	4	2.5	159	61	416	0.89
204–207	Leukemia and aleukemia	3	0.9	328	113	951	4.80[e]
202,203,208,209	Cancer of other lymph tissue	1	0.9	116	16	813	0.02
280–289	Diseases of blood	0	0.3	0	0	0	0
290–317	Mental and psychoneurotic disorders	3	0.8	394	139	1118	6.62[e]
390–458	Diseases of circulatory system	68	63.3	108	91	126	0.76
460–519	Nonmalignant respiratory disease	12	9.2	131	76	225	0.97
492	emphysema	4	1.6	245	96	628	3.50
571	Cirrhosis of liver	3	2.6	115	38	350	0.06
950–959	Suicide	4	2.5	162	64	414	1.02
	All other causes of death	17	27.3	62	39	100	3.89

[a]International Classification of Disease, 8th Revision.
[b]Obs, observed number of deaths.
[c]Exp, expected number of deaths.
[d]PMR, (Obs/Exp) × 100.
[e]$p < 0.05$.

TABLE III. Distribution of Leukemia and Hematologic Deaths Delineated by Occupation/ Industry, Age, and Type

Occupation/Industry	Code	Age group (years) 20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	Total
Auto mechanics	505	1[a]			1[c]	2[b,d]	2[e,f]	2[g,h]		8
Gasoline service station industry	621		1[b]		1[a]				1[e]	3

[a]Acute myelogenous leukemia.
[b]Chronic myelogenous leukemia.
[c]Erythroleukemia.
[d]Aplastic anemia.
[e]Chronic lymphocytic leukemia.
[f]Acute leukemia (unspecified).
[g]Chronic leukemia (undifferentiated).
[h]Anemia-dysmyelopoiesis-preleukemia.

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regarding previously undetected potential associations between workplace exposures and patterns of mortality. This analysis provided the opportunity to examine the patterns of mortality of more than 200 industrial and 500 occupational groups. The patterns of mortality for automobile mechanics and workers in the gasoline service station industry are presented because of the paucity of epidemiologic information regarding work in these trades.

The patterns of mortality of automobile mechanics and workers in the gasoline service station industry suggest that these tradesmen experience an increased leukemia risk. The PMR for leukemia among the combined group of observed deaths (N = 9) is 211 (95% CI 116, 400; $p < 0.05$). This finding is consistent with reports noting an increased risk of leukemia among men occupationally exposed to petroleum products relating to gas station and auto mechanic jobs [Milham, 1983; Dubrow and Wegman, 1984; Brandt et al, 1978]. Because work history and exposure data are unavailable, no conclusion can be drawn regarding a particular etiologic agent. However, among the potentially responsible chemical agents known to be present in service stations and garages, most suspect would be gasoline and other solvents containing benzene. The leukemogenic potential of benzene is well known and has been demonstrated among workers in a variety of trades including the shoe, rubber, petrochemical, and refining industries [Aksoy, 1980; Infante et al, 1977; McMichael et al, 1975; Thomas et al, 1980; Vigliani, 1976].

In addition to leukemia, benzene exposure is known to increase the risk of nonmalignant blood disorders including anemia, pancytopenia, and aplastic anemia. The findings of one death from aplastic anemia and another from "anemia-preleukemia" are consistent with previous case reports of these diseases related to benzene exposure [Vigliani, 1976]. Case reports of similar nonmalignant blood disorders among workers using gasoline as a solvent have been reported by Verwilghen et al [1975].

Further, the finding of an excess proportion of deaths from suicide in both groups is consistent with the known neurotoxic potential of solvent exposure. Acute exposure to solvents may produce transient and reversible central nervous system symptoms including headache, dizziness, and incoordination. At higher concentrations, convulsions, loss of consciousness, and death may result. Long-term exposure to solvents can result in memory impairment and behavioral changes, including irritability, depressive symptoms, and emotional instability. Chronic, irreversible brain damage may result following prolonged exposure to high concentrations, as reported among solvent sniffers. In view of the likelihood that work in service stations involves chronic exposure, it is not surprising that auto mechanics and service station workers experience a greater proportion of deaths from suicide. This finding is supported by Guralnick's study [1963], which reported an increased suicide risk among auto mechanics, and other studies which have reported an increased risk of suicide among solvent-exposed workers, including chemists, chemical workers, and rubber workers [Li et al, 1969; Bond et al, 1986; Andjelkovich et al, 1977]. It is possible that the neurotoxic effects of workplace solvent exposure were potentiated by ethanol use [Hills and Venable, 1982]. The likelihood of ethanol use among automobile mechanics and service station workers is evidenced by the observation of deaths from cirrhosis of the liver, cancers of the buccal cavity, and alcoholism.

Gasoline is a complex mixture of hydrocarbons blended with a combination of additives, including antiknock agents, inhibitors, and dyes. Of the more than 40

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components, most are paraffins, naphthenes, aromatics, and olefins. The benzene content of gasoline is between 1% and 3% by volume and is higher in unleaded than in leaded fuels [McDermott and Voss, 1979]. Industrial hygiene studies of service station employees have found the time-weighted average (TWA) exposure to benzene among service station workers to range from below 1 ppm to 2.08 ppm (mean range 0.02–0.24 ppm) [McDermott and Vos, 1979]. The TWA exposure to total gasoline vapor ranged from below 1 ppm to 114 ppm. Exposure levels were influenced by the workload, weather conditions, work practices, and presence of a vapor recovery system.

In addition to inhalation, these workers likely risked exposure through skin absorption if hands were immersed in gasoline or other solvents during the process of auto repair and related degreasing operations or if gasoline was used as a solvent to aid in hand washing. Recent animal studies reveal that approximately 1% of benzene applied to skin may be absorbed percutaneously [Susten et al, 1985]. Further, it is possible that gasoline was ingested if workers siphoned gasoline by mouth.

Recent data indicate that gasoline vapor may be carcinogenic apart from its benzene component. An inhalation study of rats and mice produced renal carcinomas and sarcomas with some evidence of a dose-response relationship [MacFarland et al, 1984]. Further, a review of the epidemiologic literature by Enterline and Viren [1985] revealed some evidence supporting the association between gasoline exposure and kidney cancer in humans. An excess of kidney cancer was not observed in the present analysis. Although there is a good correlation between substances that cause cancer in experimental animals and their ability to cause cancer in humans, there is not, however, always a good correlation between the specific sites of cancer observed in experimental animals and in humans.

The finding of a lung cancer excess among automobile mechanics is consistent with their potential exposure to asbestos arising from brake and clutch repair. Based on small numbers of deaths, an excess of gastrointestinal cancer was observed; however, the PMR for nonmalignant respiratory diseases was not elevated. Service station workers experienced an elevated PMR for emphysema; however, lung cancer mortality was not increased. Because asbestosis is often misdiagnosed as chronic obstructive lung disease, the observed excess of emphysema mortality among these workers may in fact reflect an increase in asbestos-related lung disease. Additional clinical data would be needed to determine the exact pathology of the observed cases.

STUDY LIMITATIONS

PMR analyses are known to have some limitations. In particular, because the all-cause mortality must equal 100%, an over- or under-representation of one cause may influence the PMR of other causes of death (the so-called "see-saw" effect). However, no deficit in cardiovascular disease (the major cause of mortality in the United States) was present in our data, which might otherwise have tended to spuriously inflate the PMR for cancer. Further, the SMOR analysis, which focuses on an odds ratio rather than cause-specific proportions, produced results virtually identical to the PMR analysis. This analysis adds confidence that the observed increased leukemia risk is not the result of the "see-saw" effect. Other limitations could stem from use of the national mortality rates to derive the expected number of deaths and the inability to control for potentially confounding factors, such as cigarette

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smoking and social class. Although the New Hampshire population is known to have experienced an excess total cancer mortality rate compared to the national rate, a mortality excess has not been exhibited for leukemia [Riggan et al, 1983]. Furthermore, epidemiologic studies have not implicated cigarette smoking or socioeconomic status as major risk factors for leukemia [Linet, 1985].

The potential limitations stemming from the use of death certificate data are well known. It is possible that nonrandom misclassification of cause of death or occupational/industrial information influenced the results by either raising or lowering the leukemia risk observed. In addition, the analysis of the industrial rather than the occupational category for gasoline service station workers may have biased the overall exposure of the group. For example, managers and owners may have had minimal workplace exposure. Alternatively, these individuals may have experienced considerable exposure, especially if they assisted in maintenance or repair operations or worked in the trade early in their careers as entry-level employees. If the former is true, the study findings suggest that the risk of leukemia associated with low-level benzene exposure may be greater than previously believed. If the latter is true, then it is possible that the overall level of exposure among individuals in this industry may be higher than previously reported. Further, because many causes of death were examined and many comparisons made, some of the study findings may be due to chance.

CONCLUSION

This analysis suggests that one or more of the exposures experienced by automobile mechanics and service station workers poses a carcinogenic risk. Although numerous agents are suspect, the finding of a leukemia excess among automobile mechanics and workers in the gasoline service station industry is consistent with exposure to benzene, a known component of gasoline. In view of the large occupational and nonoccupational population at risk of exposure, these findings serve to support the need for more definitive studies. In the interim, prudent public health practice requires the need to inform auto mechanics, gas station employees, and other individuals who pump gasoline of the potential cancer hazard. Recommendations should include discontinuing the use of gasoline as a solvent for removing grease from auto parts and for hand cleansing and cautioning against siphoning gasoline by mouth. Further, the use of vapor recovery systems could help to reduce occupational and general environmental exposure to gasoline and benzene vapors during the refueling process, thus reducing the cancer risk.

REFERENCES

Andjelkovich D, Taulbee J, Symons M, Williams T (1977): Mortality of rubber workers with reference to work experience. J Occupational Med 19:397–405.

Aksoy M (1980): Different types of malignancies due to occupational exposure to benzene: Review of recent observations in Turkey. Environ Res 23:181–190.

Bond GG, McLaren EA, Baldwin CL, Cook RR (1986): An update of mortality among chemical workers exposed to benzene. Br J Indust Med 43:685–691.

Brandt L, Nilsson PG, Mitelman F (1978): Occupational exposure to petroleum products in men with acute non-lymphocytic leukaemia. Br Med J i.553.

Bureau of Labor Statistics (1986): "Employment and Earnings." Washington, DC: U.S. Dept. of Labor, 33:187.

HWBUI0007517

Dubrow R, Wegman DH (1984): "Occupational Characteristics of Cancer Victims in Massachusetts 1971–1973." Cincinnati; U.S. Dept. of Health and Human Services, Centers for Disease Control, NIOSH Publ. No. 84–109.

Enterline PE, Viren J (1985): Epidemiologic evidence for an association between gasoline and kidney cancer. Environ Health Perspect 62:303–312.

Guralnick L (1963): "Mortality by Occupation and Cause of Death Among Men 20 to 64 Years of Age, United States, 1950." Washington, DC: U.S. Dept. of Health Education and Welfare; Public Health Service Special Report 53.

Hills BW, Venable, HL (1982): The interaction of ethyl alcohol and industrial chemicals. Am J Indust Med 3:321–325.

Infante PF, Rinsky RA, Wagoner JK, Young RL (1977): Leukemia in benzene workers. Lancet 2:76–78.

Li FP, Fraumeni JF, Mantel N, Miller RW (1969): Cancer mortality among chemists. J Natl Cancer Inst 43:1159–1164.

Linet MS (1985): "The Leukemias, Epidemiologic Aspects." New York: Oxford University Press.

MacFarland HN, Ulrich CE, Holdsworth CD, Kitchen DN, Halliwell WH, Blum SC (1984): A chronic inhalation study with unleaded gasoline vapor. J Am Coll Toxicol 3:231–247.

McDermott HJ, Vos GA (1979): Service station attendants' exposure to benzene and gasoline vapors. Am Indust Hygiene Assoc J 40:315–321.

McMichael AJ, Spirtas R, Kupper LL, Gamble JF (1975): Solvent exposure and leukemia among rubber workers: An epidemiologic study. J Occupational Med 17:234–239.

Miettinen OS, Wang J (1981): An alternative to the proportionate mortality ratio. Am J Epidemiol 114:144–148.

Milham S (1983): "Occupational Mortality in Washington State, 1950–1979." Cincinnati; U.S. Dept. of Health and Human Services, Centers for Disease Control, NIOSH Publ. No. 83–116.

Monson RR (1974): Analysis of relative survival and proportional mortality. Computers Biomed Res 7:325–332.

Peterson GR, Milham S (1980): "Occupational Mortality in the State of California 1959–1961." Cincinnati; U.S. Dept. of Health and Human Services, Centers for Disease Control, NIOSH Publ. No. 80–104.

Registrar General (1979): "Decennial Supplement for England and Wales, 1970–1972: Occupational Mortality." London: Office of Population Censuses and Surveys, Her Majesty's Stationery Office.

Riggan WB, Acquavella JF, Mason TJ (1983): "U.S. Cancer Mortality Rates and Trends, 1950–1979." Washington, DC: NCI/USEPA, EPA-600/1-83-015a.

Schwartz E, Grady K (1986): "Patterns of Occupational Mortality in New Hampshire 1975–1985." Concord, NH: N.H. Division of Public Health Services.

Susten AS, Dames BL, Burg JR, Niemeier RW (1985): Percutaneous penetration of benzene in hairless mice: An estimate of dermal absorption during tire-building operations. Am J Indust Med 7:323–335.

Thomas TL, Decoufle P, Moure-Eraso R (1980): Mortality among workers employed in petroleum refining and petrochemical plants. J Occupational Med 22:97–103.

U.S. Bureau of the Census (1982): "1980 Census of the Population—Classified Index of Industries and Occupations." Washington, DC: U.S. Dept. of Commerce.

U.S.D.H.E.W. (1968): "International Classification of Diseases, 8th Revision." Washington, DC: U.S. Public Health Service.

Verwilghen RL, Van Dorpe A, Veulemans H (1975): Dangers of petrol used as a solvent. Lancet ii.1156.

Vigliani EC (1976): Leukemia associated with benzene exposure. Ann NY Acad Sci 271:143–151.

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