American Journal of Industrial Medicine 15:531–543 (1989)

Minnesota Highway Maintenance Worker Cohort Mortality Study: Methods and Noncancer Mortality

David L. Parker, MD, MPH, Alan P. Bender, DVM, PhD, Rebecca A. Johnson, MPH, Wendy K. Scharber, ART, CTR, Allan N. Williams, MS, MPH, Marian C. Marbury, ScD, and Jack S. Mandel, PhD

In 1984, the Minnesota Department of Health (MDH) began a cohort mortality study of 4,849 workers to follow up concerns with the health and safety of highway maintenance workers (HMWs). A total of 1,530 deaths had occurred, resulting in a standardized mortality ratio (SMR) of 91 ($p < .01$) and an all cancer SMR of 84 ($p < .01$). There was a significant elevation in the SMR for chronic renal failure among long-term rural workers (SMR = 676, $p < .05$). The SMR was also elevated for transportation injuries. The latter SMR was highest among short-term urban workers (SMR = 280, $p < .01$). In addition, the SMR for transportation-related injury deaths tended to increase the later the decade of starting work. The SMRs were 137, 259, 502, and 2,145 for urban workers starting work in the decades 1945–1954, 1955–1964, 1965–1974, and 1975–1984, respectively. This study demonstrates the possible adverse health effects of highway maintenance work and the need to comprehensively evaluate injury mortality among selected occupational cohorts.

Key words: highway maintenance, injury, renal disease, diabetes, transportation accidents

INTRODUCTION

In 1984, the Minnesota Department of Transportation (MNDOT) and the American Federation of State, County, and Municipal Employees (AFSCME, Council 6) consulted the Minnesota Department of Health (MDH) about the health and safety of highway maintenance workers (HMWs). Concern was expressed about an apparent excess of injury and leukemia deaths, as well as several cases of acute lead intoxication among these workers. Based on a review of industrial hygiene data, worksite analyses, and epidemiologic literature, the MDH concluded that a large-

Chronic Disease and Environmental Epidemiology, Minnesota Department of Health, Minneapolis (D.L.P., A.P.B., R.A.J., W.K.S., A.N.W., M.C.M.).
Division of Occupational and Environmental Health, University of Minnesota, School of Public Health, Minneapolis (J.S.M.).
Dr. Parker was an EIS Officer from the Centers for Disease Control assigned to the Minnesota Department of Health.
Address reprint requests to Dr. David L. Parker, Chronic Disease and Environmental Epidemiology, Minnesota Department of Health, 717 Delaware Street, S.E., P.O. Box 9441, Minneapolis, Minnesota 55440.
Accepted for publication October 31, 1988.

scale study of all causes of mortality was necessary to address the health issues of importance to HMWs. This decision was based on several factors.

1. There are at least 500,000 HMWs nationwide.
2. Highway maintenance is an occupation whose mortality experience had not been systematically studied.
3. There is a broad range of potential workplace exposures experienced by HMWs [Bender et al., 1989].
4. Most highway maintenance work takes place on or near busy roads and involves the frequent use of heavy machinery as well as hot asphalt products. During winter months, snowplows are operated at high speed on wet and icy roads, often in subzero temperatures. A review of MNDOT worker compensation claims revealed the presence of both serious and fatal injuries.

After consideration of these issues, it was determined that to evaluate the possible health impact of highway maintenance work in Minnesota, a retrospective cohort mortality study was necessary. The following report outlines the methods used in that study and presents the results for noncancer mortality. (The interested reader may obtain a complete copy of the study report by writing to Dr. David Parker.)

MATERIALS AND METHODS

Cohort Definition

For the purpose of this study, highway maintenance was defined as the preservation and upkeep of a highway, to the extent practical, in its original condition or its subsequently improved condition. The upkeep of highways includes repairing road surfaces, sealing joints, maintaining shoulders, and repairing and improving drainage structures. Maintenance operations also include many traffic services, such as sanding roads and the removal of snow and ice. Other operations included in highway maintenance are the maintenance and construction of road signs and traffic markers, weed control, and general maintenance of the right-of-way [Tessman, 1970].

Approximately 80,000 personnel and payroll records of all those ever employed by the MNDOT were reviewed. Jobs were defined as either highway maintenance work or other (e.g., supervisor or foreman). Jobs included in the HMW category were defined on the basis of a review of job descriptions and discussions with union and MNDOT personnel.

The records of 9,406 workers ever holding a HMW job were abstracted by trained abstracters. For each worker, any specific time period during his career was classified as either HMW or "other." During the abstracting process, manual and computerized quality control procedures were used to evaluate completeness, accuracy, and consistency.

After the cohort was established, all white male workers with one or more years as a HMW who worked at least 1 day after January 1, 1945, were traced to ascertain vital status as of December 31, 1984. Workers were traced by a variety of methods, including the Social Security Administration (SSA), the National Death Index (NDI), state departments of motor vehicles, telephone directories, and state vital records systems.

For those who died in Minnesota, workers were matched by computer to death certificate information maintained by the Minnesota Center for Health Statistics and the original nosologic classification was obtained. Persons who died in other states had the underlying cause of death abstracted from the death certificate if the nosologic code was legible. For workers who had no underlying cause of death recorded on their death certificate, the cause of death was coded according to the coding scheme in use during the year in which they died. All coding was done by a certified nosologist at the MDH.

ICD Classifications

The HMW study spanned four decades and five revisions of the International Classification of Diseases (ICD). In this study, the method used to code mortality data from different ICD revisions was to construct equivalent cause-of-death categories across the years spanned by ICD revisions. Causes of death coded by different ICD revisions were "translated" into a unique set of codes [Klebba, 1975, 1980]. The level of specificity of these codes corresponded to that of the least specific revision of the ICD.

The translation codes used in this study were a modified set of codes derived from the National Institute of Occupational Safety and Health (NIOSH) classification scheme (NIOSH, personal communication). The NIOSH codes were changed primarily because of the availability of mortality data in Minnesota for the 1940s that were not available nationally. In addition, codes were added to evaluate specific causes of injury mortality of interest in this cohort. A total of 142 cause-of-death categories were used.

Comparison Population

The comparison population for the HMW cohort was white male Minnesotans. A matrix containing the number of deaths categorized by 142 causes of death, age, sex, race, and geographic regions (rural and urban) was created for each year. This matrix represented the aggregated causes of death for 1.3 million Minnesotans for the years 1945–1984. The number of deaths by age (5-year intervals) and calendar period (10-year intervals) for white males were used.

Census data were compiled by age, race, sex, and geographic region for the calculation of mortality rates. The midpoints of the four calendar periods used in the study were census years (i.e., 1950, 1960, 1970, and 1980). Therefore, the figures from the Minnesota census reports for the above years were used in estimating the numbers of Minnesota residents for these calendar periods in order to calculate baseline mortality rates.

Due to varying rates of mortality by region, both the cohort and comparison populations were divided into two regions: urban and rural. Persons in the comparison population were classified as urban if they were residents of Hennepin County (i.e., Minneapolis), Ramsey County (i.e., St. Paul), the city of Duluth, or the city of Rochester. All other persons were classified as rural. Cohort members were classified as urban if they started work in Minneapolis or St. Paul; all other workers were considered rural.

Data Analysis

Standardized mortality ratios (SMRs) were computed with indirect standardization [Hill, 1972]. The estimate of the expected number of deaths for the HMW cohort

TABLE I. Description of Highway Maintenance Worker Cohort

Subgroup	No. of workers	Mean years worked (SE)[a]	Mean age beginning work (SE)	Mean age ending work (SE)	Mean year starting work
All workers	4,849	13.9 (.15)	35.3 (.17)	49.9 (.21)	1957
Urban workers	1,508	11.3 (.22)	34.7 (.32)	46.5 (.38)	1963
Rural workers	3,341	15.1 (.19)	35.5 (.20)	51.5 (.24)	1955

[a]SE = standard error.

was calculated by applying the age, sex, race, and time-specific cause of death rates for the Minnesota population to the age, sex, race, and time-specific number of years of follow-up contributed by the HMWs [Fleiss, 1981; Monson, 1974, 1978]. Years of follow-up (person-years) took into consideration the number of persons and the length of follow-up for each person. Follow-up in this study began January 1, 1945, for persons with 1 or more years of experience at that date. Follow-up began on the first-year anniversary of employment as a HMW for all other persons. Study participants contributed person-years of follow-up until death, loss to follow-up, or termination of the study (December 31, 1984).

Patterns of mortality were computed by combinations of the following variables: age at death, calendar year of death, age started work, year started work, years worked, and latency. Latency was defined as the time from when a person first started work (i.e., first date as a HMW) until death, loss to follow-up, or termination of the study. Significance levels were computed for the ratio of an observed to expected value of a Poisson variable [Bailar and Ederer, 1964], as well as the Mantel-Haenszel estimate of the odds ratio and the Mantel-Haenszel chi-square statistic.

RESULTS

Tracing

A total of 4,326 (89.2%) records of 4,849 workers who were eligible for the study were sent to the SSA; 523 (10.8%) workers had no social security number and were not sent to the SSA. Four of those determined to be alive by the SSA were known from work records to be deceased.

Various methods were used to determine the vital status of workers whose names were not sent to or not found by the SSA. In general, a comprehensive search of Minnesota death certificates was the most useful means of locating deceased cohort members. Telephone tracing and motor vehicle records were the most useful means for locating living cohort members who were not identified by the SSA or had no social security number. For those not sent to the SSA, 418 (79.9%) were deceased, 89 (17.0%) were alive, and 16 (3.1%) had an unknown vital status. Vital status was determined for 4,831 (99.6%) of 4,849 workers. Eighteen (0.4%) workers were lost to follow-up.

Cohort Description

Approximately one-third of the cohort was urban and two-thirds of the cohort was rural (Table I). Rural workers tended to start work at the MNDOT at an older age

TABLE II. Summary SMRs for the Minnesota Highway Maintenance Worker Cohort—Noncancer Mortality

Cause of Death (ICD-9)	Observed	Expected	SMR	95% confidence interval
All causes (001–999)	1,530	1,676.0	91	(86, 96)
All infective and parasitic (001–139)	11	14.7	75	(38, 134)
All cancer (140–208)	274	328.8	83	(73, 94)
Nutritional, metabolic and immune diseases (240–279)	39	32.8	119	(85, 163)
Hematopoietic disorders (280–289)	4	4.0	100	(27, 256)
Psychiatric disorders, alcoholism (290–319)	4	4.2	96	(26, 246)
Neurologic diseases (320–389)	14	17.3	81	(44, 136)
All circulatory (390–459)	865	950.5	91	(85, 97)
All heart disease	677	727.0	93	(86, 100)
Ischemic heart	601	627.9	96	(88, 104)
Cerebrovascular	130	162.5	80	(66, 95)
Arteriosclerosis	16	19.0	74	(35, 136)
All respiratory (460–519)	105	102.9	102	(83, 123)
Chronic and unspecified bronchitis	7	4.8	147	(59, 303)
Emphysema	19	20.2	94	(57, 147)
Diseases of the digestive system (520–579)	53	63.8	85	(64, 111)
Cirrhosis of liver	19	24.0	79	(48, 123)
Diseases of genito-urinary system (580–629)	17	22.1	77	(45, 123)
Diseases of skin (680–709)	0		0	
Bone and connective tissue diseases (710–739)	5	3.3	153	(50, 357)
Senility and ill-defined conditions (780–799)	13	13.1	99	(53, 169)
All E codes (800–999)	116	110.5	105	(87, 126)
Other injuries[a]	44	44	100	(73, 134)
Transportation injuries (E800–E848, E929.0, E939.1)	53	38.4	138	(103, 180)
Residual and undefined	1	0.8	119	(3.0, 661)

[a]Does not include suicide and homicide.

and work for the MNDOT longer than their urban counterparts. The largest number of workers entered the cohort during the 1950s and 1960s and between their 20th and 30th birthdays. A total of 4,849 workers contributed 96,567 person-years to this study.

Mortality

The overall SMR in this cohort for all causes of death was 91 ($p < .01$) (Table II). The reduced mortality experience was independent of the number of years worked, latency, and decade of hire. All three major causes of death contributed to this deficit: cancer, circulatory diseases, and cerebrovascular disease.

There were 274 cancer deaths. The overall SMR for all cancer deaths was 83 ($p < .01$). The SMR for leukemia (107) tended to increase in later decades of starting work [Bender et al., 1989]. A total of 865 of 1,530 deaths (57%) was attributed to all circulatory diseases. The overall SMR for circulatory diseases was 91 ($p < .05$). The two major contributors to this category of death were ischemic heart disease with 601 deaths (SMR = 96) and cerebrovascular diseases with 130 deaths (SMR = 80, $p < .05$). There were no significant differences in overall cardiovascular mortality or in specific subcategories (i.e., ischemic heart disease) between urban and rural workers, and there were no trends in mortality when examined by duration of work, year of hire, or latency.

TABLE III. Ratio of Observed Deaths to Expected Number of Deaths by Year Started Work for Accidents in Minnesota HMW Cohort

Year started	SMR (N)[a]	95% confidence interval
1900–1924	55 (2)	(7, 199)
1925–1934	95 (10)	(46, 175)
1935–1944	69 (16)	(39, 112)
1945–1954	141 (20)	(86, 218)
1955–1964	164 (24)	(105, 244)
1965–1974	168 (21)	(104, 257)
1975–1984	286 (4)	(78, 732)

[a]Number in parentheses is the number of observed deaths.

Accidents included deaths caused by falls, poisoning, transportation mishaps, and other injuries (Table II). There were 97 deaths listed as accidents and the overall SMR was 121. There was an indication of an increasing SMR with the later years of starting work (Table III).

The overall SMR for deaths resulting from transportation accidents (e.g., boat, automobile, or truck) was 138 ($p < .05$) (Table IV). Of the 53 deaths in this category, 14 were determined from the death certificate to have occurred at work. As seen in Tables IV and V, the overall SMR was greater for urban than for rural workers. In addition, mortality was greater for short- than for long-term urban workers. The opposite pattern was seen for rural workers.

For urban workers who did only highway maintenance during their career there was a pronounced mortality trend with the year started work. As seen in Table IV, the SMR for these HMWs increased over the decades 1945–1954, 1955–1964, 1965–1974, and 1975–1984. For these same time periods, workers with less than 5 years of experience had SMRs of 0, 255, 469, and 2,410 (not shown), respectively. Neither of these trends was seen for rural workers who did only highway maintenance during their career.

Based on 44 deaths, the overall SMR for "other" accidents (e.g., falls, drowning, or electrocution) was 100 for the entire cohort. There was no difference between urban and rural workers. No trend was seen for age or decade in which a person started work or the total number of years worked. Ten of these deaths were reported on the death certificate to have occurred at work with the MNDOT.

Based on 30 deaths, there was a nonsignificant (SMR = 120) excess of diabetes deaths. There were no indications of a relationship between diabetes and the number of years worked or the year starting work. Based on ten deaths, the overall SMR for urban workers was 190; based on 20 deaths, the overall SMR for rural workers was 103. For all workers during the years 1965–1974, 18 deaths occurred, resulting in an SMR of 210 ($p < .01$). During the same years, the SMR for urban workers was 330 ($p < .05$), and the SMR for rural workers was 180.

Deaths caused by diseases of the genitourinary system were primarily due to renal failure and infections of the urinary tract. The overall SMR was 77, based on 17 deaths. Nearly half of these deaths were due to chronic renal failure. In addition, the SMRs were 0, 61, 132, and 176 for those who died in the decades 1945–1954, 1955–1964, 1965–1974, and 1975–1984, respectively. The largest increase was seen for rural workers. On the basis of three deaths from chronic renal failure, rural workers with 50 years of latency had an SMR of 676 ($p < .05$).

TABLE IV. SMRs for State, Urban, and Rural Workers for Transportation Accidents by Year Started in Minnesota HMW Cohort

	State		Urban		Rural	
Year started	HMW only[a]	All workers[b]	HMW only	All workers	HMW only	All workers
1900–1924	0 (0)	70 (1)	0 (0)	0 (0)	0 (0)	70 (1)
1925–1934	0 (0)	139 (6)	0 (0)	0 (0)	0 (0)	148 (6)
1935–1944	108 (5)	94 (9)	0 (0)	0 (0)	122 (5)	103 (9)
1945–1954	133 (5)	103 (7)	137 (1)	86 (1)	125 (4)	100 (6)
1955–1964	138 (5)	140 (11)	259 (3)	341[c] (7)	84 (2)	67 (4)
1965–1974	274[c] (8)	201[c] (15)	502[d] (6)	253 (6)	139 (2)	184 (9)
1975–1984	833[d] (4)	422[c] (4)	2,145[d] (3)	1,467[d] (3)	301 (1)	127 (1)
Total	171[c] (27)	138[c] (53)	330[d] (13)	223[c] (17)	118 (14)	113 (36)

[a]HMW only: HMWs with only highway maintenance worker experience.
[b]All workers: all work time included regardless of job classification, i.e., workers who did both highway maintenance and some other work during their career.
[c]$p < .05$.
[d]$p < .01$.

TABLE V. SMRS for State, Urban, and Rural Workers for Transportation Accidents by Number of Years Worked in Minnesota HMW Cohort

	State		Urban		Rural	
Years worked	HMW only[a] (N)	All workers[b] (N)	HMW only (N)	All workers (N)	HMW only (N)	All workers (N)
0–4	191[c] (16)	135 (20)	392[d] (9)	280[d] (10)	117 (7)	87 (10)
5–9	147 (5)	139 (11)	344 (3)	274 (5)	80 (2)	97 (6)
10–19	128 (4)	135 (12)	155 (1)	131 (2)	118 (3)	131 (10)
20–29	131 (1)	88 (4)	0 (0)	0 (0)	142 (1)	93 (4)
30–39	816 (1)	319[c] (6)	0 (0)	0 (0)	866 (1)	320[c] (6)
40+	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	171[c] (27)	138[c] (53)	330[d] (13)	233[d] (17)	118 (14)	113[c] (36)

[a]HMW only: HMWs with only highway maintenance worker experience.
[b]All workers: all work time included regardless of job classification, i.e., workers who did both highway maintenance and some other work during their career.
[c]$p < .05$.
[d]$p < .01$.

DISCUSSION

The lower overall mortality (SMR = 91) for HMWs may be explained partly by the healthy-worker effect. It has been suggested that part of this effect may be secondary to the use of an inappropriate comparison population [Wen et al., 1983]. In this study, MNDOT workers were compared with all Minnesotans of the same age, sex, and race; over the same time period; and from a similar rural or urban setting.

Although this method of comparison does not eliminate the healthy-worker effect, in this setting, other Minnesotans were considered the best comparison population. For most diseases, Minnesotans have lower mortality rates than the general population of the United States. If the higher mortality rates of the United States were used to determine the expected number of deaths, the resultant number

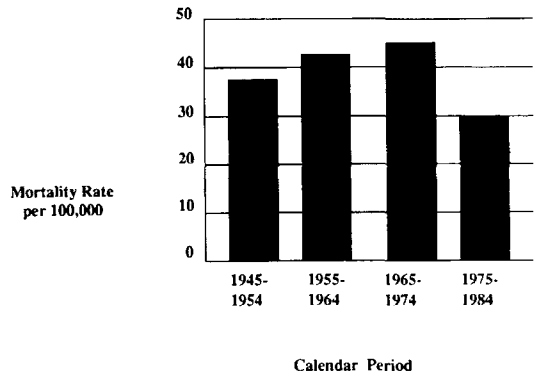

Fig. 1. Age-adjusted mortality rates for transportation accidents in Minnesota for white males.

of expected deaths would have been greater (for most causes), which consequently would have produced lower and misleading SMRs. Therefore, a comparison of the mortality of HMWs to the mortality of the entire United States would have masked real excesses of mortality in HMWs. For some diseases such as leukemia, however, the Minnesota mortality is higher than the United States. In this instance, the use of national data would have overestimated the significance of leukemia mortality in this cohort.

It has also been suggested that the healthy-worker effect may in part be secondary to incomplete follow-up and inaccurate determination of vital status [Wen et al., 1983; Vena et al., 1987]. In this cohort, over 99.6% of cohort workers were traced, and death certificates were obtained on all but two of the deceased. Despite the fact that follow-up was complete and a regional comparison population was used, the healthy-worker effect may have had a strong influence on this cohort. Because a person must be in relatively good health to start working and to remain working, workers in general will experience less mortality than the population as a whole, which includes persons too ill to work or too ill to work in physically demanding jobs such as highway maintenance. This selection process in the work force has been extensively described [Wen et al., 1983; McMichael, 1976; Seltzer and Jablon, 1974].

Injuries

Death certificates listed 14 workers as having died from transportation accidents while at work with the MNDOT. It was determined later that three other workers had died while working for the MNDOT. No specific type of transportation injury was apparent from a review of death certificates. However, as seen in Table IV, transportation-related deaths appear to be an emerging problem.

Part of the increasing SMR seen in later years may be accounted for by the decrease in age-adjusted mortality from transportation accidents for white male Minnesotans. As shown in Figure 1, age-adjusted mortality for transportation-related deaths increased slightly between the decades 1945–1954 and 1965–1974, and age-adjusted mortality decreased from 44 per 100,000 in 1965–1974 to 30 per 100,000 in 1975–1984. The SMRs for HMWs for the periods 1945–1954, 1955–1964, 1965–1974, and 1975–1984 were 103, 140, 201, and 422, respectively.

Thus, the SMRs for transportation accidents have been increasing steadily over time in this cohort. This increase has been in both relative and absolute terms when compared with other Minnesotans. Urban workers were affected more than rural workers; similarly, those who did only highway maintenance work were affected more than those who did highway maintenance and other work. Less experienced workers were affected more than their senior peers. The cause for these increases is not apparent.

It is possible that less senior workers are given less desirable jobs to perform and these jobs place a worker at increased risk. As worker seniority increases, they may move into less hazardous job positions. Another possibility is that injury risk to younger workers may be a reflection of lack of experience. Both of these possibilities have been suggested by Waller [1985]. Younger age (18–24 years) and shorter job experience have also been shown to be related to a higher incidence of work-related injuries reported in the Supplementary Data System [Root, 1981]. However, the relationship between age, experience, and incidence of injury may vary between industrial facilities [Waller, 1985].

In the present study, for transportation-related injury mortality, less work experience was a factor for urban workers but not rural workers. When occupationally related deaths were removed from the SMR computations, the trend for mortality increasing with decreasing job experience disappeared. In addition, the trend seen with decade starting work remained, but weakened. These findings support the conclusion that the trends seen are related to some aspect of work. The nature of this relationship could not be defined further.

Although the SMRs for "other" accidents (i.e., falls, electrocution) were not increased, there were ten injurious deaths at the workplace from nontransportation-related causes. Three of the ten deaths were a result of falling machinery, and two were a result of workers falling 10 or more feet. Causal factors could not be further clarified from a review of death certificate data.

There have been several studies of safety practices in highway construction zones [Hargroves, 1978; Davis, 1983]. These studies, however, examine risk factors related to public motoring in roadway repair zones and not to specific work practices. From a review of death certificates and accident investigation reports, it does not appear that injurious deaths in this cohort were concentrated in highway construction zones. Maizlish et al. [1986] found an increase in the proportional mortality (PMR = 141, $p < .01$) related to motor vehicle deaths for California Department of Transportation workers. The job classifications and duration of work were unknown, and more specific comparisons of risk between the two studies are not possible.

As is often the case with death by injury, mortality may reflect only a small portion of total morbidity. Most injuries do not result in mortality. For example, in 1983 in Minnesota, there were 481 fatalities and 39,103 personal injuries resulting from automobile crashes. This means nonfatal injuries outnumbered fatal injuries 80 to 1 for motor vehicular crashes. During the same year, there were 48 road-maintenance vehicle crashes, and none of these was fatal [Minnesota Department of Public Safety, 1983]. In order to further evaluate injury morbidity among HMWs, worker compensation data files were reviewed for the years 1984–1986. There were 236 injuries related to trucks, tractors, and/or other vehicles and 301 injuries related to falls. The severity and cause of these injuries could not be determined from data

that have been collected to date. The back, fingers, knee, and eye were the most common injury sites.

Because of the known connection between traffic safety, injury, and alcohol use [NHTSA, 1985], several causes of death known to be associated with alcohol were examined to determine whether there was any evidence of excessive alcohol use among HMWs. Alcohol use has been strongly associated with deaths due to falls, suicide, cirrhosis, pancreatitis, and oral and laryngeal cancers [Parker et al., 1987]. The SMRs for these causes were 83, 59, 79, 96, and 87, respectively. Aggregating the five causes of alcohol-related deaths gave an overall SMR of 70. These observations suggest that alcohol use was lower among HMWs than among Minnesotans in general.

The acquisition of more and better surveillance data is a prerequisite to the study of injuries. In general, there is a lack of detailed information on the groups of workers susceptible to injuries. Data on ergonomic, behavioral, and environmental factors are essential for planning and evaluation of prevention programs, both within and outside the workplace [Thomas et al., 1985]. The need for intervention programs is supported by these data; however, recent studies have questioned the efficacy of existing programs in the construction industry [Dedobbeleer and German, 1987].

This study also points out the need to evaluate injuries in occupational cohorts. It is not sufficient merely to examine all injury deaths or all "E" codes. Rather, it is necessary to construct categories of injuries to evaluate the occupation that is being studied. In this cohort, the elevation in transportation-related injury deaths was a significant finding that would have been lost without multiple categories of injury mortality.

Other Noncancer Deaths

Thirty deaths resulted from diabetes. The overall SMR for diabetes was 120. A statistically significant increase was seen in those who started work 1965–1974. The increase in these years was seen for both rural and urban workers. Several chemical agents are known to cause diabetes. These substances include alloxan, streptozotoxin, and, as a secondary effect, alcohol [Dulin et al., 1983].

Diabetes is a disease that has not been commonly associated with occupation. Reports from early this century indicated that diabetes was more common among the "learned professions," occupations exposed to alcohol (e.g., brewers), and butchers. Diabetes was negatively associated with hard labor of all kinds. Later reports also indicated that there may have been differences in the prevalence of diabetes in different occupational groups. These differences, however, have not been well defined [West, 1978].

Diabetes is a complex illness influenced by many factors such as heredity, race, geography, parity, exercise, nutrition, socioeconomic status, and infection. We know of no reports associating diabetes with the exposures of interest in this study. These exposures include asphalts [NIOSH, 1977], benzene [Haley, 1977; Decouflé et al., 1983], 2,4,-D [Clement Associates, 1984], gasoline, diesel fumes, and polycyclic aromatic hydrocarbons [NAS, 1983]. In the absence of a dose-response relationship or exposure to an agent known to cause diabetes, it seems unlikely that the increases seen here were the result of highway maintenance work.

Based on three deaths, there was an SMR of 676 for chronic renal failure for rural workers with greater than 50 years of latency. Many chemicals such as heavy

metals, silica, pesticides, and organic solvents may cause renal failure [Ganse et al., 1985; Landrigan et al., 1984]. Of these exposures, lead and organic solvents are most germane to this cohort. To date, we have no environmental data on lead exposure to HMWs. Lead has also been associated with cerebrovascular disease and other hypertensive sequelae [Selevan et al., 1985]. In this cohort, the SMR for hypertensive heart disease was 66 (n = 13), and for cerebrovascular disease, the SMR was 80 (n = 130).

Over the past 5 years, solvent-exposure data have been collected in sign-painting shops and during road asphalting processes within the MNDOT. All exposures have been well below the threshold limit value for petroleum distillates, xylene, benzene, hexane, and toluene. In two cases series examining chronic renal disease and solvent exposure, no specific substances were identified and exposures were assessed by work history [Ehrenreich et al., 1977; Beirne and Brennan, 1972]. Other case series have specifically identified carbon tetrachloride and trichloroethylene as acute nephrotoxins [Gutch et al., 1965; Guild et al., 1958] and gasoline as a cause of chronic glomerulonephritis [Churchill et al., 1983]. Further study is needed to characterize the relationship between solvents and chronic renal disease. At present, solvents are best classified as suspect nephrotoxins [Landrigan et al., 1984]. Additional occupational and environmental data are being collected to help characterize the possible relationship between highway maintenance work and renal disease.

SUMMARY

The 1,530 deaths observed among the HMW cohort were 9% fewer than expected. Most of this deficit came from the three major categories of death: cancer, heart disease, and cerebrovascular disease. Despite the favorable overall mortality, this study points to several health and safety risks that may be experienced by HMWs. Most important are injurious deaths among short-term workers. Injuries have been identified by NIOSH as one of the ten leading causes of work-related morbidity and mortality [NIOSH, 1985]. Injuries are the leading cause of years of potential life lost, and rank fourth as an overall cause of death in the United States [Thomas et al., 1985]. In addition, transportation injuries account for about 40% of occupational fatalities in the United States [Waller, 1985]. Although in some instances elevations were found for other causes of mortality (e.g., renal disease and diabetes), it appears unlikely that these observations are related to the HMW work experience. Efforts are underway to further characterize lead, carbon monoxide, solvents, asphalt, and other possible environmental exposures to HMWs. In addition, case control studies are being conducted for renal disease and injuries to help characterize the job experiences of workers who died of these causes.

This study also demonstrates the importance of evaluating the mortality from all causes and not simply examining a single cause of mortality. The initial problem presented to the MDH was an elevation of leukemia; had leukemia been the focus of all subsequent investigations, other equally important problems may have been missed.

ACKNOWLEDGMENTS

This work was supported in part by a NIOSH SERCA award numbered OH0055-02 and by a grant from the Minnesota Department of Transportation. Special

assistance was provided by the American Federation of State, County, and Municipal Employees (Council 6) and the Minnesota Department of Transportation.

REFERENCES

Bailar JC, Ederer F (1964): Significance factors for the ratio of a Poisson variable to its expectation. Biometrics 20:639–643.

Beirne GJ, Brennan JT (1972): Glomerulonephritis associated with hydrocarbon solvents. Arch Environ Health 25:365–369.

Bender AP, Parker DL, Johnson RA, Scharber WK, Williams AN, Marbury MC, Mandel JS (1989): Minnesota highway maintenance worker study: Cancer mortality. Am J Ind Med 15:545–556.

Churchill DN, Fine A, Gault MH (1983): Association between hydrocarbon exposure and glomerulonephritis. An appraisal of the evidence. Nephron 33:169–172.

Clement Associates (1984): "Review of Literature on Herbicides, Including Phenoxy Herbicides and Associated Dioxins: Analysis of Recent Literature on Health Effects." Vol. 3. Arlington, VA: Clement Associates, Inc.

Davis TD (1983): "Construction Zone Safety and Delineation Study." Trenton, NJ: New Jersey Department of Transportation (Publication No. FHWA/NJ-83/005).

Decouflé P, Blattner WA, Blair A (1983): Mortality among workers exposed to benzene and other agents. Environ Res 30:16–25.

Dedobbeleer N, German P (1987): Safety practices in construction industry. J Occup Med 29:863–869.

Dulin WE, Gerritsen GC, Chang AY (1983): Experimental and spontaneous diabetes in animals. In Ellenberg M, Rifkin H (eds): "Diabetes Melitus—Theory and Practice." New York: Medical Examination Publishing Company, pp 361–408.

Ehrenreich T, Yunis SL, Churg J (1977): Membranous nephropathy following exposure to volatile hydrocarbons. Environ Res 14:35–45.

Fleiss JL (1981): "Statistical Methods for Rates and Proportions," 2nd ed. New York: John Wiley & Sons, pp 237–254.

Ganse WV, Caroyer JM, Vanavermaet S (1985): Glomerulonephritis and organic solvents. Lancet 2:1126–1127.

Guild WR, Young JV, Merrill JP (1958): Anuria due to carbon tetrachloride intoxication. Ann Intern Med 48:1221–1227.

Gutch CF, Tomhave WG, Stevens SC (1965): Acute renal failure due to inhalation of trichloroethylene. Ann Intern Med 63:128–134.

Haley J (1977): Evaluation of the health effects of benzene inhalation. Clin Toxicol 11:531–548.

Hargroves BT (1978): "Vehicle Accidents at Maintenance and Utility Work Zones." Charlottesville, VA: Virginia Highway and Transportation Research Council (Publication No. VHTRC 79-R22).

Hill ID (1972): Computing man years at risk. Br J Prev Soc Med 26:132–134.

Klebba JA (1975): "Comparability of Mortality Statistics for the Seventh and Eighth Revisions of the International Classification of Diseases, United States." Rockville, MD: United States Department of Health, Education, and Welfare, Public Health Service (Publication No. 76-1340).

Klebba JA (1980): Estimates of selected comparability ratios based on dual coding of 1976 death certificates by the eighth and ninth revisions of the International Classification of Diseases. Mon Vital Stat Rep 28:1–18.

Landrigan PJ, Goyer RA, Clarkson TW, Sandler DP, Smith JH, Thun MJ, Wedeen RP (1984): The work-relatedness of renal disease. Arch Environ Health 39:225–230.

Maizlish N, Beaumont J, Singleton J (1986): "Mortality Among Highway Transportation Workers, Final Report." Davis, CA: Occupational and Environmental Health Unit, University of California at Davis.

McMichael AJ (1976): Standardized mortality ratios and the "healthy worker effect": Scratching beneath the surface. J Occup Med 18:165–168.

Minnesota Department of Public Safety (1983): "Crash Facts, State of Minnesota." St. Paul, MN: Minnesota Department of Public Safety.

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

Monson RR (1978): USDR Users Guide. Boston: Harvard University (unpublished abstract).

National Academy of Sciences, Committee on Pyrene and Selected Analogues (1983): "Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects." Washington, DC: National Academy of Sciences.

National Highway Traffic Safety Administration (1985): "Alcohol and Highway Safety 1984: A Review of the State of the Knowledge." Washington, DC: US Department of Transportation (Publication No. DOT-HS-806-569).

NIOSH (1977): "Criteria for a Recommended Standard for Occupational Exposure to Asphalt Fumes." Washington, DC: US Department of Health, Education and Welfare, Public Health Service.

NIOSH (1985): Leading work-related diseases and injuries—United States. MMWR 34:219–222.

Parker DL, Schultz JM, Gertz LM, Remington PL, Berkelman R (1987): The social and economic consequences of alcohol abuse in Minnesota. Am J Public Health 77:982–986.

Root N (1981): Injuries at work are fewer among older employees. Monthly Labor Review, March, 30–34.

Selevan S, Landrigan PJ, Stern FB, Jones JH (1985): Mortality of lead smelter workers. Am J Epidemiol 122:673–683.

Seltzer CC, Jablon S (1974): Effects of selection on mortality. Am J Epidemiol 100:367–372.

Tessman GF (1970): "Minnesota Highway Maintenance Costs—A Study of Financial Requirements Through 1986." St. Paul, MN: Minnesota Department of Highways, Management Services Section.

Thomas RD, Pope AM, Giese L, Grossblatt N (1985): "Injury in America—A Continuing Public Health Problem." Washington, DC: National Academy Press, p. 23.

Vena J, Sultz HA, Carlo GL, Fiedler RC, Barnes RE (1987): Sources of bias in cohort mortality studies: A note on treatment of subjects lost to follow-up. J Occup Med 29:256–261.

Waller JA (1985): "Injury Control: A Guide to the Causes and Prevention of Trauma." Lexington, MA: Lexington Books, pp 421–445.

Wen CP, Tsai SP, Gibson RL (1983): Anatomy of the healthy worker effect: A critical review. J Occup Med 25:283–289.

West KM (1978): "Epidemiology of Diabetes and Its Vascular Lesions." New York: Elsevier Press.