American Journal of Industrial Medicine 27:759–770 (1995)

Mortality in a Cohort of Antimony Smelter Workers

Teresa M. Schnorr, PhD, Kyle Steenland, PhD, Michael J. Thun, MD, and Robert A. Rinsky, MS

Animal studies show that antimony may cause lung cancer and heart and lung disease in rodents. In exposed humans, ECG abnormalities and heart and lung disease have been reported. This mortality study of 1,014 men employed between 1937 and 1971 in a Texas antimony smelter consisted primarily of workers of Spanish ancestry (n = 928, 91.5%). Hispanics are known to smoke at much lower rates than non-Hispanics, and their lung cancer and heart disease mortality is generally low. When ethnic-specific Texas lung cancer death rates were used for comparison, mortality from lung cancer among antimony workers was elevated (SMR) 1.39, 90% CI 1.01–1.88), and we observed a significant positive trend in mortality with increasing duration of employment. When ischemic heart disease death rates from three different Spanish-surnamed populations were used for comparison, the rate ratios for mortality from ischemic heart disease were 0.91 (90% CI 0.84–1.09), 1.22 (90% CI 0.78–1.89), and 1.49 (90% CI 0.84–2.63). Pneumoconiosis/ other lung disease death rates for Spanish-surnamed men were unavailable and so calculation of rate ratios used white males as a comparison population (SMR 1.22; 90% CI 0.80–1.80). These data suggest some increased mortality from lung cancer and perhaps nonmalignant respiratory heart disease in workers exposed to antimony. However, conclusions are limited by possible confounders and the difficulty of identifying appropriate referent groups.

Key words: antimony, heart disease, lung cancer, mortality, minorities, Hispanics

INTRODUCTION

Antimony is a brittle metal obtained through refining of base metal and silver ores. It can be combined with oxygen to form antimony oxides, which are used as a flame retardant in plastics and textiles. Antimony can also be mixed with other metals to increase their hardness, mechanical strength, or corrosion resistance [ATSDR, 1991]. Although very little antimony is mined in the United States, it is one of the major consumers of antimony compounds, importing raw ore from Latin America, China, Hong Kong, and South Africa for production of antimony metal and trioxide [U.S. Bureau of Mines, 1989]. Of all antimony imported into the United States in 1988, ~55.3% was metal, 31.9% oxide, 12.4% ore and concentrate, and 0.4%

Division of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, Cincinnati, Ohio.
Michael J. Thun is now with the American Cancer Society, Atlanta, GA.
Address reprints to Teresa M. Schnorr, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, R-15, Cincinnati, OH 45226.
Accepted for publication August 1, 1994.

sulfide [U.S. Bureau of Mines, 1989]. According to a 1983 estimate, >370,000 workers are potentially exposed to antimony compounds [NIOSH, 1989]. A smaller number of workers (~2,000) is estimated as exposed to antimony at facilities that manufacture or process antimony compounds [ATSDR, 1991].

Animal studies show that antimony is carcinogenic [Groth et al., 1986; Watt, 1983]. Two toxicologic studies found increased lung cancer in female rats inhaling antimony trioxide [Groth et al., 1986; Watt, 1983] and antimony ore concentrate [Groth et al., 1986]. In one study of female rats, 87% exposed to a small particle size (0.44 μm) at 45 mg/m^3 for a 6 hour/day time-weighted-average (TWA) of antimony trioxide over a 1-year period developed lung neoplasms, whereas no control rats or rats exposed to 1.6 mg/m^3 developed lung cancer [Watt, 1983]. In a second study, 27% of female rats exposed to a larger particle size (2.8 μm) at 45 mg/m^3 for a 7-hour/day TWA of antimony trioxide over a 1-year period developed lung cancer and 25% of female rats exposed to 36–40 mg/m^3 (TWA) of antimony ore developed lung cancer. None of the control rats developed lung cancer [Groth et al., 1986] nor did any of the male rats exposed or unexposed. A third study of rats exposed to an even larger particle size (3.8 μm) at 3.76 mg/m^3 of antimony trioxide did not show an increase in lung tumor incidence [Bio/dynamics, 1989]. A possible explanation for absence of lung cancer in the third study is the larger particle size of the antimony aerosol [ATSDR, 1991].

The International Agency for Research on Cancer (IARC) has determined that there is sufficient evidence for the carcinogenicity of antimony trioxide in animals. However, there is inadequate evidence for classification in humans [IARC, 1989]. The only human data for antimony are described in a brief report [Davies, 1973] printed in 1973, which discussed a retrospective cohort mortality study of antimony smelter workers conducted in England. Nine lung cancer deaths were found among workers employed in smelting activities, whereas only 5.7 lung cancer deaths were expected (standardized mortality ratio (SMR) 158, 95% confidence interval (CI) 72-300) [Davies, 1973]. Antimony air concentrations taken in 1961 ranged between 10–18,360 μg/m^3. Arsenic exposure in this same smelter ranged between 3–108 μg/m^3. IARC has determined that there is sufficient evidence to consider arsenic a human carcinogen [IARC, 1987]. Because raw antimony ore contains some arsenic and because arsenic is an established lung carcinogen, it is difficult to separate the effects of antimony and arsenic in an observed excess of lung cancer in smelter workers.

Antimony trisulfide has been associated with myocardial tissue damage in both animals and humans. One limited epidemiologic study, initiated after eight workers died suddenly from heart disease in an antimony plant, implicated antimony trisulfide with heart disease and ECG abnormalities (primarily of T waves) in exposed workers [Brieger et al., 1954]. After a follow-up period of unspecified length, ECG abnormalities persisted in 12 of 56 affected workers. The long-term implications of these ECG changes are unclear. The investigators of this cluster also conducted some animal inhalation studies that showed degenerative changes in the myocardium and ECG abnormalities when compared to control animals [Brieger et al., 1954]. Supporting evidence for the cardiotoxicity of antimony is found among patients who received arsenic-free antimony drugs for treatment of parasitic infections. Temporary ECG changes were observed in patients treated with antimony compounds, and some patients who died during antimonial treatment were shown to

TABLE I. Composition of Antimony Ore Processed by Study Plant (1975)*

Source of ore	% Antimony	% Arsenic	% Sulfur	% Lead
Guatemala	51.2	0.072	14.00	0.286
Mexico	31.6	0.054	0.46	0.136
Honduras	40.3	0.072	0.44	0.110
Bolivia	59.6	0.126	18.50	0.396

*Unanalyzed portions of the ores consisted mainly of silicates, calcium and iron oxides, plus some trace metals. Source: Donaldson [1979].

accumulate antimony in the myocardium [Honey, 1960; Sapire and Silverman, 1970; Tarr, 1947].

Nonmalignant respiratory effects also have been observed in animals and humans exposed to antimony. Pulmonary fibrosis was found in male and female rats exposed to antimony trioxide and antimony ore [Groth et al., 1986]. Human studies have associated pneumoconiosis and alterations in pulmonary function (airways obstruction, bronchospasm, and hyperinflation) with workplace exposure to antimony metal and trioxide dust [Cooper et al., 1968; Potkonjak and Pavlovich, 1983].

To determine whether workers experienced excess mortality from lung cancer, cardiovascular disease, or nonmalignant respiratory disease, we conducted a mortality investigation at an antimony smelter in southern Texas. The plant under study was built in 1930 to recover antimony metal and oxide from ore mined in Mexico and other areas in Central and South America. In a process that changed little from 1930 until the plant closed in 1979, ore was reacted with coke, iron oxide, and other fluxes in a blast furnace where it was refined to 85–90% antimony content. The metal was further refined in a reverberatory furnace. From this point, the metal was either sent to a starring furnace for additional refining, or sent to the oxide furnace where antimony oxide was formed, volatilized to a fine powder, and collected in bags.

The primary source of the ore was a mine in Mexico owned by the same company that owned the smelter. Ore was also purchased from Honduras, other Central and South American countries, and occasionally from China. Table I shows the antimony and arsenic content of the ore as measured in bulk samples taken in 1975 [Donaldson and Cassady, 1979]. The antimony ore was composed primarily of antimony oxide or antimony sulfide.

No exposure data were available for 1930–1974. However, two NIOSH industrial hygiene surveys of the smelter were conducted in 1975 and 1976 [Donaldson and Cassady, 1979]. Both surveys measured airborne fume and dust exposures to antimony and arsenic in all areas of the plant. Eight-hour time-weighted-averages are shown in Table II. The geometric mean antimony levels of 12 area samples taken in 1975 and 50 personal samples taken in 1976 were 551 $\mu g/m^3$ and 747 $\mu g/m^3$, respectively. Both surveys showed antimony levels in excess of the then current OSHA antimony standard of 500 $\mu g/m^3$, which has not changed. Area samples of arsenic taken in 1975 showed a geometric mean of 2 $\mu g/m^3$ and personal samples in 1976 of 5 $\mu g/m^3$, below the current arsenic OSHA standard of 10 $\mu g/m^3$ and well below the then current standard of 500 $\mu g/m^3$.

MATERIALS AND METHODS

The study population included 91 white and 923 Spanish-surnamed males hired between January 1, 1937 and July 1, 1971 and employed for a minimum of 3 months.

TABLE II. Industrial Hygiene Estimates of Antimony and Arsenic Levels (1975 & 1976)*

			Airborne level ($\mu g/m^3$)			
			Antimony[a]		Arsenic[b]	
Time period	Samples	Operation	Range	Geometric Mean	Range	Geometric Mean
1975[c]	3	Blast furnace	110–1,100	316	1–7	2
	1	Reverberatory furnace	1,100	—	3	—
	3	Starring furnace	520–1,200	882	2–3	2
	1	Casting area	2,000	—	4	—
	1	Warehouse	610	—	2	—
	1	Oxide furnace	140	—	1	—
	1	Charge scale	360	—	1	—
	1	Change room	540	—	1	—
	12	Total plant	110–2,000	551	1–7	2
1976[d]	4	Blast furnace	410–1,800	1,091	5–13	8
	4	Reverberatory furnace	890–2,100	1,382	2–10	5
	6	Oxide furnace	90–3,100	1,498	8–37[e]	19
	8	Maintenance	90–6,200	239	1–17	2
	22	Laborers	90–4,900	851	1–41	6
	6	Miscellaneous	50–3,700	543	1–47	4
	50	Total plant	50–6,200	747	1–47	5

*Source: Donaldson [1979].
[a]OSHA standard for antimony currently and at the time of the survey was 500 $\mu g/m^3$.
[b]OSHA standard for arsenic at the time of the survey was 500 $\mu g/m^3$.
[c]Eight-hour area samples.
[d]Eight-hour breathing zone samples.
[e]One arsenic value of 160 $\mu g/m^3$, believed by the industrial hygienist to be an error, was dropped.

Work histories were obtained through 1975, when employment records were obtained. Because company personnel records were not complete, we identified the population through company payroll records that contained the following data: name, date of birth, social security number, dates of pay for time worked. Job title or department data were not available for the employees.

We conducted vital status follow-up through the Social Security Administration, Internal Revenue Service, Veterans Administration, Health Care Finance Administration, National Death Index, state departments of Motor Vehicles, credit bureaus, U.S. Post Office, and local funeral directors. The vital status of each worker was determined as of December 31, 1989. Death certificates were obtained and coded by a qualified nosologist according to the revision of the International Classification of Disease that was in effect at the time of death.

The mortality experience of the cohort was analyzed with the use of the NIOSH modified lifetable analysis system (LTAS) [Steenland et al., 1990; Waxweiler et al., 1983]. A worker accumulated person-years at-risk (PYAR) for every year of life following completion of the eligibility period (in this study at 3 months employment). Person-years at-risk continued to accumulate until either his death, date last observed (for persons lost to follow-up), or the study end date (for persons alive at the study end date). These PYARs were stratified by 5-year age, calendar time, duration of employment strata, and 10-year latency periods. The expected number of deaths between 1940–1989 was calculated by multiplying the U.S. white male cause-specific death rates within each age, calendar-time, duration, and latency PYAR cate-

gory. The resulting expected numbers were summed over strata to obtain the cause specific and total expected number of deaths. The ratio of observed to expected deaths was expressed as the standardized mortality ratio (SMR).

For rate ratios of a priori hypotheses of lung cancer, cardiovascular disease, and pneumoconioses/other lung disease, 90% confidence intervals were computed assuming a Poisson distribution for the observed deaths [Rothman and Boice, 1979]. For all other outcomes, we computed 95% confidence intervals.

The primary analyses for lung cancer and heart disease utilized Spanish-surnamed populations as the comparison groups. This was done because the cohort was composed primarily of Spanish-surnamed men and because mortality from lung and heart disease among such populations is markedly lower than among white males [Martin and Suarez, 1987; Rogot et al., 1988]. For example, in 1980 in a population of one million Americans, lung cancer and heart disease rates among Mexican-American males were 77% and 63% of the rate for white males [Rogot et al., 1988]. Spanish-surnamed men are also known to smoke fewer cigarettes than white males, which could contribute to the relative deficit of lung cancer and heart disease deaths [Mitchell et al., 1990; Samet et al., 1982].

To determine the number of Spanish-surnamed members of the cohort, we matched the surnames of study subjects to a computer tape of such surnames from the 1980 census [U.S. Bureau of the Census, 1980] and determined that 923 (91.5%) of the members of the cohort were Spanish-surnamed.

Cancer Mortality Analysis Using Spanish-Surnamed Death Rates

A special set of cancer rates was obtained from the Texas State Health Department, whose investigators calculated Spanish-surnamed cancer death rates by using the surnames to identify Mexican-Americans in U.S. census surveys and on death certificates [Martin and Suarez, 1987]. The Texas Health Department provided the rates for each available age and calendar year period for three cancer sites (lung, liver and biliary tract, and stomach) among Spanish-surnamed men in Texas. Death rates for the latter two cancers were obtained by way of a check on the validity of the rates since mortality from these cancers is generally higher among Spanish-surnamed populations than among the general population of U.S. white males [Martin and Suarez, 1987]. In all analyses using the Texas state rates, person-time at risk did not start until 1960, when state death rates were available.

Cancer death rates for Spanish-surnamed men in Texas were available from the Health Department only for two 5-year periods, 1970–74 and 1980–84. To obtain 1975–79 rates, we interpolated the mortality rates for two surrounding time periods (1970–74 and 1980–84). Rates for 1960–64 and 1965–70 were assumed to be the same as those for 1970–75. Similarly, 1985–89 rates were assumed to be the same as those for 1980–84. Spanish-surnamed cancer death rates prior to 1960 were not estimated.

For lung, stomach, and liver and biliary cancer, we calculated the expected number of deaths for the 923 Spanish-surnamed males using the 1960–84 Texas Spanish-surnamed rates described above, and we calculated the expected number of deaths for the 91 white males in the cohort using the 1960–84 Texas white male rates. We then summed these quantities over all ages, years, and ethnicity to obtain the total expected deaths in the antimony cohort.

Cardiovascular Mortality Analysis Using Three Different Spanish-Surnamed Rates

The study of cardiovascular disease was constrained by the absence of national or state mortality data for Spanish-surnamed men. Thus we examined cardiovascular disease mortality using three different study populations: population-based rates among Mexican-American men included in a mortality study of one million people [Rogot et al., 1988], mortality rates among Spanish-surnamed men included in a study of a cadmium smelter [Thun et al., 1985], and population-based rates among Spanish-surnamed men in New Mexico [Becker et al., 1988].

The first comparison utilized a population of 15,711 Mexican-American men included in a U.S. National mortality study of one million people [Rogot et al., 1988]. In this analysis, we used the age-specific rates of ischemic heart disease deaths among Mexican-American men between 1979–81 as the referent rates. Ethnicity was assigned according to self-report in an interview, rather than surname matching. These rates were available for the years 1979–81. Lacking any knowledge of trends over time, we decided it was reasonable to assume they remained constant during the period 1975–89. Correspondingly, we restricted our cohort data (observed deaths and person-years) to the same time interval when using the "one-million-people" rates as referent rates. We then calculated standardized rate ratios (SRRs) using Poisson regression [Frome and Checkoway, 1985]. The 91 white men were excluded from this analysis.

Second, we selected a comparison population of Spanish-surnamed men (n = 225; person-years = 6,252) employed in a Colorado cadmium smelter between 1940 and 1969 [Thun et al., 1985]. We chose this cohort because cadmium has not been associated with ischemic heart disease and because the workers had the same ethnic background as our cohort and were employed during approximately the same time period (1940–69). We used the age-specific cardiovascular disease rates among the Spanish-surnamed men in the cadmium cohort between 1940 and 1989 as referent rates for the Spanish-surnamed men in the antimony population. The 91 white men in the antimony cohort were also excluded from this analysis.

Third, we selected a comparison population of Spanish-surnamed New Mexico men. For this analysis, we obtained a set of ischemic heart disease death rates stratified by age and calendar period from the University of New Mexico School of Medicine [Becker et al., 1988]. Mortality rates were available for the intervals 1958–62, 1963–67, 1968–72, 1973–77, 1978–82. Rates for 1983–89 were assumed to be the same as those for the 1978–82 interval. The 91 white men in the antimony cohort were also excluded from this analysis.

Nonmalignant Respiratory Disease

Spanish-surnamed populations also have been reported to have lower prevalence of nonmalignant respiratory disease than white populations [Samet et al., 1982]. Unfortunately, we were unable to locate Spanish-surnamed mortality rates for nonmalignant respiratory disease. Therefore, our only analysis is that using U.S. white males as the comparison group.

RESULTS

The analysis was restricted to the 91 white and 923 Spanish-surnamed males due to the small numbers of females (n = 17) and nonwhite males (n = 21). Table

TABLE III. Characteristics of the Antimony Smelter Study Population

No. of workers	1,014		
No. of person years at risk	33,773		
Vital status as of 12/31/89:			
	Total No. (%)	*Spanish-surnamed* No. (%)	*White* No. (%)
Alive	403 (39.7)	363 (39.3)	40 (44.0)
Dead	579 (57.1)	530 (57.4)	49 (53.8)
Unknown	32 (3.2)	30 (3.3)	2 (2.2)
Average age at first employment	32		
Average year of first employment	1943		
Average length of employment (yr)	6.8		
Average length of follow-up (yr)	35		

III shows the characteristics of the study population. The number of cause-specific deaths in the overall cohort compared with the number expected, based on U.S. white male rates is shown in Table IV. Deaths from all causes were lower than expected (SMR = 0.94; 95% CI 0.86–1.01). Mortality from specific causes showed a pattern expected in a population that is primarily Spanish-surnamed. As expected, overall cancer mortality (SMR 0.88; 95% CI 0.72–1.06) was slightly lower than expected. This was primarily due to the lower lung and colon cancer mortality generally found in Spanish-surnamed populations.

Whereas the overall SMR for lung cancer compared to white males was reduced (0.75; 90% CI 0.54–1.02), lung cancer mortality among men with the longest time since first exposure (> 20 years) and the longest duration of employment (> 10 years) was elevated, but not significantly (9 observed; SMR 1.55; 90% CI 0.86–2.60). All but two of the 30 lung cancer deaths occurred 20 years or more after first employment.

As is typical of Spanish-surnamed populations, heart disease mortality was also reduced. Overall cardiovascular disease mortality was significantly reduced in this cohort (SMR 0.59; 90% CI 0.50–0.70) when compared to U.S. white males. This deficit was primarily due to a marked deficit in ischemic heart disease (SMR 0.49; 90% CI 0.41–0.57) (Table IV).

The antimony population showed elevations in mortality from liver and stomach cancer when compared to U.S. white males. A significant excess in mortality was observed for cancers of the liver, biliary tract, and gall bladder (n = 7 deaths; SMR 3.17; 95% CI 1.27–6.52) (Table IV). Stomach cancer was elevated, but not significantly (SMR 1.49; 95% CI 0.71–2.74).

One finding that did not follow the general pattern of Spanish-surnamed populations was mortality from nonmalignant respiratory disease. Nonmalignant respiratory disease is normally lower among Spanish-surnamed populations when compared to U.S. rates [Samet et al., 1982]. However, we observed a slight nonsignificant increase (SMR = 1.09; 95% CI 0.80–1.44). When we looked at specific respiratory disease categories, we found that the antimony cohort showed a nonsignificant deficit in emphysema and bronchitis deaths (SMR 0.59) and slight elevations in mortality from influenza and pneumonia (SMR 1.23), as well as the a

TABLE IV. Mortality from Major Causes of Death Using U.S. White Male Mortality Rates as Comparison

Cause of death (ICD 9 code)	Observed	Expected	SMR	95% CI
All causes	579	618.08	0.94	0.86–1.01
All cancers (140–208)	111	126.65	0.88	0.72–1.06
All digestive system (150–159)	29	36.42	0.80	0.53–1.14
Stomach (151)	10	6.71	1.49	0.71–2.74
Liver and gallbladder (155–156)	7	2.21	3.17	1.27–6.52
Colo-rectal (153–154)	2	16.19	0.12	0.01–0.45
All respiratory system (160–163)	34	42.19	0.81	0.56–1.13
Trachea, bronchus, and lung (161)	30	39.92	0.75	0.54–1.02*
Buccal cavity and pharynx (140–149)	4	3.56	1.12	0.31–2.88
Male genital organs (185–187)	8	11.79	0.68	0.29–1.34
Urinary organs (188–189)	3	7.18	0.42	0.09–1.22
Lymphatic and hematopoietic (200–208)	8	11.03	0.72	0.31–1.43
Unspecified sites (194–199)	25	14.29	1.75	1.12–2.55
Nonmalignant respiratory (460–519)	48	44.22	1.09	0.80–1.44
Influenza and pneumonia (480–487)	21	17.05	1.23	0.76–1.88
Emphysema and bronchitis (490–492)	6	10.17	0.59	0.22–1.28
Pneumoconiosis and other (470–478,494–519)	19	15.52	1.22	0.80–1.80*
Heart disease (390–398,402,404,410–414,420–429)	154	262.66	0.59	0.50–0.70
Ischemic heart disease (410–414)	106	218.13	0.49	0.41–0.57*
Other circulatory system (401,403,405,415–417,430–459)	61	64.85	0.94	0.72–1.21
Digestive system (520–579)	30	26.85	1.12	0.75–1.60
Genitourinary system (580–629)	15	9.65	1.55	0.87–2.56
Diabetes mellitus (250)	16	8.88	1.80	1.03–2.93
Tuberculosis (001–008)	6	5.57	1.08	0.39–2.34
Accidents (E800–949)	31	28.29	1.10	0.74–1.56
Violence (E950–978)	18	12.01	1.50	0.89–2.37
Ill-defined conditions (780–793,795)	27	6.06	4.46	2.94–6.48

*90% confidence intervals are given for these a priori causes of death.

priori category of pneumoconiosis/other respiratory diseases (SMR 1.22; 90% CI 0.80–1.80) (Table IV). Of the 19 deaths in this last category, 12 were due to pneumoconiosis or pulmonary fibrosis and the SMR among men with >10 years employment was 2.68 (90% CI 1.26–5.03).

Additional analyses for cancer and cardiovascular disease were conducted utilizing death rates among Spanish-surnamed populations as the referent groups.

Analysis of Cancer Mortality Using Ethnic-Specific Rates

Table V shows that mortality from lung cancer was elevated when we used Texas Spanish-surnamed rates for Spanish-surnamed members of the cohort and Texas white male rates for white cohort members (N = 28; SMR 1.39; 90% CI 1.01–1.88). Two lung cancer deaths that occurred in the 1950s were omitted from this analysis since the state rates were available beginning in 1960. There was a significant positive trend ($\chi^2 = 8.30$, $p < 0.005$) [Breslow et al., 1983] in mortality with increasing duration of employment.

When using the Texas ethnic-specific rates as the comparison, the SMR due to liver, biliary tract, and gall bladder cancer was increased (n = 6 deaths; SMR 1.58; 95% CI 0.57–3.44) as was stomach cancer (n = 7 deaths; SMR 1.24; 95% CI

TABLE V. Mortality from Lung Cancer Since 1960 Using Ethnic-Specific Texas Death Rates, According to Duration of Employment

Ethnic category	Duration of employment			Total (90% CI)
	<5 yr	5–10 yr	>10 yr	
Combined white and Spanish-surnamed SMR[a]	0.83	2.24	2.73	1.39 (1.01–1.88)
(no. observed)	(11)	(8)	(9)	(28)
Spanish-surnamed SMR	0.69	2.52	2.99	1.40 (0.91–2.07)
(no. observed)	(8)	(8)	(9)	(25)
White male SMR	1.78	0.00	0.00	1.27 (0.26–3.72)
(no. observed)	(3)	(0)	(0)	(3)

[a]χ^2 trend = 8.30, $p<0.005$ [Breslow, 1983].

0.50–2.55), but this elevation for both causes was lower than when U.S. white male rates were used.

Cardiovascular Mortality Among Spanish-Surnamed Men

When we used the New Mexico Spanish-surnamed ischemic heart disease rates to examine ischemic heart disease deaths among the 923 Spanish-surnamed men in the cohort, we did not observe an elevated SRR (0.91; 90% CI 0.84–1.09). However, when we used the Mexican-American (1979–81) comparison population from a U.S. survey [Rogot et al., 1988] as the reference, we found an elevated SRR for ischemic heart disease deaths (SRR 1.49; 90% CI 0.84–2.63; 48 observed deaths). Using the Spanish-surnamed cadmium cohort as a comparison population, we also found an elevated SRR for ischemic heart disease deaths (SRR 1.22; 90% CI 0.78–1.89). Using the cadmium comparison group, we looked for a trend with duration of employment but found none. We also tried to examine whether mortality from cardiovascular disease decreased with cessation of exposure by looking at mortality in relation to time since last employment but did not observe a trend with time since last employment.

DISCUSSION

In this study of data in antimony smelter workers, the findings of primary interest were increased mortality from lung cancer and heart and nonmalignant respiratory disease. We found an increase in lung cancer mortality when we used ethnic specific-state mortality rates. We also observed a statistically significant increasing risk of lung cancer mortality with increasing length of employment. Use of ethnic-specific rates for this analysis was important since studies have shown that Spanish-surnamed males have a lung cancer mortality rate that is 0.52 that of the U.S. white male rate [Martin and Suarez, 1987]. Differences in smoking habits may partially explain the lower mortality for Spanish-surnamed males. Mortality from other smoking related cancers (oral cavity and bladder) is also decreased among Spanish-surnamed males, and some studies have shown that Spanish-surnamed men smoke fewer cigarettes than do white males [Martin and Suarez, 1987; Samet et al., 1982].

The possibility should be considered that the increased mortality from lung cancer might be due to arsenic exposure at the smelter. If we assume that respirators were not worn, then the estimated average daily arsenic exposure level was 5 $\mu g/m^3$,

TABLE VI. Ischemic Heart Disease Mortality Using Three Different Spanish-Surnamed Populations as Comparison Groups

Comparison population	SRR (90% CI)
Mexican-American males [Rogot, 1988]	1.49 (0.84–2.63)
Spanish-surnamed cadmium workers [Thun, 1985]	1.22 (0.78–1.89)
New Mexico Spanish-surnamed rates [Samet, 1982]	0.91 (0.84–1.09)

based upon 1976 survey data. On the basis of the OSHA risk assessment model for arsenic [Department of Labor, 1982] and considering that the 1,014 workers were exposed an average of 6.8 years, such an exposure level would result in no more than 0.6 excess lung cancer deaths in this population due to arsenic whereas eight excess lung cancer deaths were observed. At the time the exposure surveys were conducted, half-mask respirators were worn by men in the production area. So, actual antimony and arsenic exposures may have been lower than the measurements indicated in Table II. However, it is also possible that our estimate of arsenic exposure is underestimated. Our estimates of arsenic exposure were based upon data collected in 1975 and 1976 and assumed that the process did not change over time. If the past sources of antimony ore contained a higher percentage of arsenic that those identified in 1975–76, or if respirators were worn improperly, actual arsenic levels may have been higher. Walk-through surveys conducted in 1975 and 1976 revealed that the smelter was an open air plant and the process did not appear to have changed from earlier years. Some of the furnaces and equipment were in operation since 1930.

We were unable to obtain Spanish-surnamed mortality rates for nonmalignant respiratory disease and therefore could not thoroughly investigate the slightly elevated SMR observed when we used U.S. comparison rates (SMR 1.09). Hispanics have been reported to have a lower prevalence of respiratory disease than non-Hispanics [Samet et al., 1982], in part explained by lower cigarette consumption. Mortality from chronic obstructive pulmonary disease had been reported to be ~50% lower among Hispanic males compared to white males [Rogot et al., 1988]. Although our study showed a deficit of mortality from smoking-related lung diseases such as emphysema and bronchitis (SMR 0.59), we found a slight elevation in mortality in the category that included pneumoconiosis and other lung disease (SMR 1.22) which was significantly elevated in men with >10 years employment (SMR 2.68). Silica exposure might be a possible explanation for the elevated pneumoconiosis mortality. Unfortunately, we had no information on silica exposure levels at the smelter. However, in two other similar antimony smelters visited during 1975, silica comprised ~4% of the antimony concentrate and 0.02% of the final antimony oxide product [Donaldson and Cassady, 1979].

The study of cardiovascular disease was constrained by the absence of national or state data on mortality for Spanish-surnamed men. For this reason, we had to rely on three comparison groups with different limitations. Although the comparison groups selected were reasonable, none was ideal. The first comparison group, Mexican-American men included in a study of one million people, covered a limited time period (1979–81) and was population-based. The antimony cohort included cardiovascular disease mortality over several decades among a working population. Thus decreased cardiovascular disease mortality over time could have inflated the SMR using this comparison group. The second group, Spanish-surnamed men employed in a cadmium smelter, was a small cohort, but the workers were employed and died

during the same time period as the study group (1940–84) so that changes in cardiovascular disease mortality over time and the healthy worker effect should not explain the positive findings using this comparison group. The New Mexico comparison group was population-based but covered a more appropriate time period than did the first population-based comparison group. The healthy worker effect could have influenced the findings in both of these population-based referent groups.

CONCLUSIONS

The results of this study of workers employed in an antimony smelter lead us to two conclusions. First, these data suggest some increase in mortality from lung cancer and perhaps ischemic heart and nonmalignant respiratory disease in workers exposed to antimony. Second, the conclusions of this study and of other occupational health studies among minority groups are limited by possible confounders and the difficulty of identifying appropriate referent groups. Better availability of appropriate comparison groups is an essential element for the effective study of these groups.

ACKNOWLEDGMENTS

We thank Drs. Jeanne Martin of the Texas State Health Department and Jonathan Samet of the University of New Mexico for sharing their mortality data with us, and Kathy Masterson, Pauline Bischak, Sue Palu, Cynthia Flesch, and Clorinda Battaglia for their support and expertise.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). "Draft for Public Comment (1991): Toxicological Profile for Antimony and Compounds." Atlanta: U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry.

Becker TM, Wiggins C, Key CR, Samet JM (1988): Ischemic heart disease mortality in Hispanics, American Indians, and non-Hispanic whites in New Mexico, 1958–1982. Circulation 78:302–309.

Bio/dynamics (1989): "A One Year Inhalation Toxicity Study of Antimony Trioxide in the Rat (with a recovery period)—Month 18 Interim Report." E. Millstone, NJ: Bio/dynamics.

Breslow NE, Lubin JH, Marek P, Langholz B (1983): Multiplicative models and cohort analysis. JASA 78(381): 1–12, Applications Section.

Brieger H, Semisch CW, Stasney J, Piatnek D (1954): Industrial antimony poisoning. Ind Med Sur 23:521–523.

Cooper DA, Pendergrass EP, Vorwald AJ, Mayock RL, Brieger H (1968): Pneumoconiosis among workers in an antimony industry. Am J Roent Radium Ther Nuclear Med 103:495–508.

Davies TAL (1973): "The Health of Workers Engaged in Antimony Oxide Manufacture—A Statement." London: Department of Employment, Employment Medical Advisory Service.

Donaldson H, Cassady M (1979): "Environmental Exposure to Airborne Contaminants in the Antimony Industry 1975–1976 Technical Report." DHEW (NIOSH) Publication No. 79-140. Cincinnati NIOSH.

Frome E, Checkoway H (1985): Use of Poisson regression in estimating incidence rates and ratios. Am J Epidemiol 121(2):309–323.

Groth DH, Stettler LE, Burg JR (1986): Carcinogenic effects of antimony trioxide and antimony ore concentrate in rats. J Toxicol Environ Hlth 18:607–626.

Honey M (1960): The effects of sodium antimony tartrate on the myocardium. Br Heart J 22:601–616.

International Agency for Research on Cancer (IARC) (1987): "IARC Monographs on the Evaluation of

Carcinogenic Risks to Humans: Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs Volumes 1 to 42," Supplement 7. Lyon, France: IARC.

International Agency for Research on Cancer (IARC) (1989): "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Some Organic Solvents, Resin Monomers and Related Compounds, Pigments and Occupational Exposures in Paint Manufacture and Painting," Vol. 47. Lyon, France: IARC.

Martin J, Suarez L (1987): Cancer mortality among Mexican Americans and other whites in Texas, 1969–80. Am J Public Health 77(7):851–853.

Mitchell BD, Stern MP, Haffner SM, Hazuda HP, Patterson JK (1990): Risk factors for cardiovascular mortality in Mexican Americans and non-Hispanic whites: The San Antonio heart study. Am J Epidemiol 131(3):423–433.

National Institute for Occupational Safety and Health (NIOSH) (1989): "National Occupational Exposure Survey (NOES)." Cincinnati NIOSH.

Potkonjak V, Pavlovich M (1983): Antimoniosis: A particular form of pneumoconiosis: I. Etiology, clinical and X-ray findings. Int Arch Occup Environ Health 51:199–207.

Rogot E, Sorlie PD, Johnson NJ, Glover CS, Treasure DW (1988): "A Mortality Study of One Million Persons by Demographic, Social and Economic Factors: 1979–1981 Follow-up. U.S. National Longitudinal Mortality Study." NIH Publication No. 88-2896. Washington, DC: DHHS, NIH.

Rothman KJ, Boice JD (1979): "Epidemiologic Analysis with a Programmable Calculator" NIH Publication No. 79-1649, Washington, DC: DHHS, NIH.

Samet JM, Schrag SD, Howard CA, Key CR, Pathak DR (1982): Respiratory disease in a New Mexico population sample of Hispanic and non-Hispanic whites. Am Rev Respir Dis 125:152–157.

Sapire DW, Silverman NH (1970): Myocardial involvement in antimonial therapy: A case report of acute antimony poisoning with serial ECG changes. S Afr Med J 44:948–950.

Steenland K, Beaumont J, Spaeth S, Brown D, Okun A, Jurcenko L, Ryan B, Phillips S, Roscoe R, Stayner L, Morris J (1990): New developments in the life table analysis system of the National Institute for Occupational Safety and Health. J Occup Med 32:1091–1098.

Tarr L (1947): Effect of the antimony compounds, fuardin and tartar emetic on the electro-cardiogram of man: A study of the changes encountered in 141 patients treated for schistosomiasis. Ann Intern Med 27:970–988.

Thun MJ, Schnorr TM, Smith AB, Halperin WE, Lemen RA (1985): Mortality among a cohort of U.S. cadmium production workers: An update. JNCI 74(2):325–333.

U.S. Bureau of the Census (1980): "1980 Census Population and Housing: Spanish Surname List, Technical Documentation." Washington, DC: US Bureau of the Census, Data Users Services Division.

U.S. Department of Labor (1982): Occupational exposure to inorganic arsenic. Occupational Safety and Health Administration. Federal Register 42(69):15358–66.

U.S. Bureau of Mines (1989): "Antimony in the First Quarter of 1989. Mineral Industry Series." Pittsburgh: U.S. Bureau of Mines.

Watt WD (1983): Chronic Inhalation Toxicity of Antimony Trioxide: Validation of the Threshold Limit Value. PhD dissertation, Wayne State University, Detroit.

Waxweiler R, Beaumont J, Henry J, Brown D, Robinson C, Ness G, Wagoner J, Lemen R (1983): A modified lifetable analysis system for cohort studies. J Occup Med 25:115–124.