Mortality of Potash Workers

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Excessive respiratory disease mortality has been noted among underground miners for centuries.[1-2] This excess risk reflects deaths largely due to pneumoconiosis, tuberculosis, and lung cancer. The pneumoconiosis and tuberculosis have been attributed to free silica although other dusts may be involved.[1-5] The excess of lung cancer has been attributed primarily to radon daughters in the air of mines,[6-8] although other agents such as arsenic, asbestos, and nickel have been implicated at times.[8-14]

Because of the observation that miners of diverse ores have experienced an excess lung cancer risk, there has been speculation that individuals who choose to work underground have a constitutional predisposition to this malignant manifestation. The primary purpose of the present epidemiological investigation was to evaluate the constitutional predisposition hypothesis among a cohort of miners exposed during their underground employment to no known carcinogens in the ore.

Eight companies from the potash mining and milling industry located near Carlsbad, N.M., agreed to cooperate in this epidemiological investigation. Potash mining began in this area in the 1930's. Potash ore is not embedded in siliceous rock as many other ores are. Instead, the ore bodies consist mainly of salts of sodium and potassium. The radon level in the air of potash mines is not significantly higher than in ambient air.[6] Other suspected lung cancer agents, such as arsenic, nickel, cobalt and chromium, if present at all, have concentrations of less than one part per million of air.[15]

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Presented at the American Industrial Hygiene Association Meeting at San Francisco, May 15-19, 1972.

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Methods

Selected for study were miners and millers who had worked at least one year between January 1940 and July 1967, at the previously mentioned potash companies. Although our interest was primarily in underground workers, it was considered advisable to include mill workers in the study for comparison purposes. Employment records of males whose job classifications indicated that they may have worked underground or at surface jobs other than unskilled general labor, transportation, or administration, were microfilmed. Omission of unskilled surface workers tended to make the surface cohort older than the underground cohort. Social Security number, birthdate, place of birth, and dates and types of all work, including a designation as to whether it was surface or underground, were abstracted from these records. Each job classification was assessed as to whether it involved surface or underground activity (or both), and the men were divided into two categories after excluding men with less than one year of experience in the potash industry or with more than one year in both surface and underground work. (1058 men): (1) Men who had one year or more of underground potash work, and less than one year of surface potash work between 1940-1967. (2743 men), and (2) Men who had one year or more of surface potash work, and less than one year underground potash work between 1940-1967. (1143 men)

Information on the vital status of study group members was obtained from a number of sources: The Social Security Administration, mail questionnaires, national tax files, telephone interviews with relatives and neighbors, state driver's license bureaus, credit bureaus, employee records, and state vital statistics departments. Through these sources the vital status, as of July 1, 1967, was determined for all but thirty-one members of the study group. These men were assumed to be alive so that any bias that might result from their indeterminate status would be one of understatement rather than overstatement.

Death certificates were obtained for 433 of the 438 potash workers reported to have died before July 1, 1967, the endpoint for this analysis. The five workers who were reported dead but for whom no death certificates were located were considered as deaths due to unknown cause. The underlying cause of death was coded from death certificates by a trained nosologist, using the revision of the "International Lists of Diseases and Causes of Death" in effect at the time of death. These codes were then converted into 7th Revision numbers using accepted rules of comparability. Persons who died overseas were treated as alive but withdrawn from the study on their date of death. Their deaths were not counted. Both the surface and underground cohorts were analyzed separately using a modified life table technique. Person-years at risk of dying were obtained by 5-year age groups, 5-year calendar-year groups, time after onset of potash work (latency), and years of potash work experience (exposure). The workers were considered at risk from their twelfth month of potash work until either their death or July 1, 1967, which ever came

Table 1. — Expected and Observed Deaths by Cause and by Type and Amount of Potash Work Experience
S = Surface Workers U = Underground Workers (Miners)

Cause of Death	List No. (ICD)**	Work Area	Years of Potash Work Experience 1-4 Exp.	1-4 Obs.	5-14 Exp.	5-14 Obs.	15+ Exp.	15+ Obs.	Total Exp.	Total Obs.
Respiratory Tuberculosis	001-008	S	1.48	2	1.75	2	.53	1	3.76	5
		U	2.33	2	1.77	1	.51	1	4.61	4
Malignant Neoplasms	140-159,	S	6.96	1*	10.89	4*	5.75	3	23.60	8*
Other than Respiratory	165-199	U	8.92	7	8.71	8	5.71	2	23.34	17
Malignant Neoplasms	160-164	S	2.56	1	3.75	5	2.63	4	8.94	10
of the Respiratory System		U	4.11	5	4.04	4	2.96	3	11.11	12
Vascular Diseases	330-334	S	5.80	5	9.25	8	4.27	5	18.52	18
of the Central Nervous System		U	4.67	8	5.06	3	3.89	2	13.62	13
Heart Diseases	400-443	S	26.80	17	43.31	31	23.16	24	98.27	72*
		U	34.78	22*	35.42	34	25.47	21	95.67	77
Other Respiratory Diseases	470-479,	S	1.19	0	1.88	2	1.31	1	4.38	3
	500-527	U	1.66	5	1.61	3	1.30	3	4.57	11*
Influenza and Pneumonia	480-493	S	1.73	0	2.74	4	1.20	2	5.67	6
		U	2.15	3	2.16	2	1.15	1	5.46	6
Violent Deaths	800-985	S	9.69	17	8.76	10	3.88	5	21.54	32*
		U	19.71	49*	13.27	26	4.25	3	37.23	75*
All Other Causes		S	15.98	10	22.16	21	9.41	3*	47.47	33*
		U	23.58	13*	21.25	9*	9.85	4	54.68	26*
Unknown		S	0.00	1	0.00	0	0.00	0	0.00	1
		U	0.00	3	0.00	1	0.00	0	0.00	4
TOTAL		S	71.31	54*	104.49	86	51.34	48	227.14	188*
		U	101.91	113	93.29	92	52.89	48	248.09	245
Person Years at Risk		S	8771		7159		2325		18254	
		U	19172		12718		3551		35333	

* Significantly different from expected at 5% level.
** ICD = International Classification of Diseases and Causes of Death

first. Comparison was made between the observed risk of dying among the study cohort, with that expected according to age, sex, race, calendar time, and cause specific mortality rates for the general population of the United States. These mortality rates were obtained by using the actual number of deaths in the U.S. and population totals from linear interpolation of U.S. Census figures.

Results

Because of the prevalence of respiratory disease among miners in general, four cause-of-death groups related to the respiratory system are given in Table 1. These are tuberculosis, malignant disease, influenza and pneumonia, and "other" which includes bronchitis, pneumoconiosis, emphysema, asthma, etc. In only one of these four was there a significant excess of observed over expected deaths. This was a small excess in the "other" category among underground workers.

There was a marked deficit of deaths from malignant neoplasms of sites other than the respiratory system among the surface cohort (8 observed vs. 24 expected). This deficit occurred without respect to years of work experience.

A small deficit of deaths due to vascular disease of the heart was noted among both surface and underground cohorts. However, most of this deficit occurred among those persons with the least experience in the industry. Observed deaths due to vascular disease of the central nervous system was the same as expected in both cohorts.

There was an excess of observed deaths from violence as compared to expected. This excess was largely due to non motor vehicle accidents among underground workers who had less than 15 years of mining experience (Table 2).

Discussion

When consideration was given to the fact that in several western mountain states (including New Mexico) lung cancer rates are only 76% of that for the total United States,[6] the observed numbers were still not statistically different (at the 5% level) from the number of deaths expected.

Furthermore, during each duration-of-employment category, no statistically significant excess of lung cancer was demonstrable. In addition, a small sample of both surface and underground potash workers who volunteered to give sputum and blood samples were interviewed regarding their smoking habits. The results (Table 3) indicated not only that a higher percent of potash workers smoked but also that they smoked at a heavier rate than United States males. This factor would increase the number of expected deaths and thus tend to counterbalance the adjustment needed for mountain states. The lack of an excessive lung cancer risk among potash miners is similar to that observed among British coal miners who are not permitted to smoke tobacco un-

derground, but who apparently compensate for this prohibition by increased smoking at other times.[16] In the potash mines, however, the workers are allowed to smoke underground.

These observations are not consistent with the hypotheses that: (1) Underground miners are predisposed to lung cancer, or (2) Underground mining (in the absence of radon daughters and other known carcinogens) is causally related to lung cancer.

The deficit of heart disease deaths was largely among those who had less than 15 years of potash work experience, rather than among those with most work experience. This suggests that the deficit was unrelated to environmental conditions in the mines and mills, but was more likely a result of self-selection and preemployment screening.

The deficit of deaths in the surface cohort from malignant neoplasms other than respiratory is puzzling. If most of the 36 untraced persons had actually died of cancer, this deficit would be accounted for. But that is unlikely. Since the deficit occurs throughout all years of work categories, it is not likely due to a job selective effect. It suggests either that the environment of the community, or of the potash mills is associated with reduced mortality from cancer. No explanation for such an association is apparent. It deserves further study. However, if the death rate in this category for surface workers is considered normal for the area, then the mortality from "malignant neoplasms other than respiratory" is significantly elevated ($p < 0.05$) among underground potash workers.

The excess of deaths in the "other" respiratory disease category (emphysema, bronchitis, asthma, pneumoconiosis, etc.) was noted only among underground workers. The excess was small (11 vs. 4.6 expected) and 5 of the 11 had pneumoconiosis. This was probably a sequelae of prior non-potash mining in siliceous rock which these five men had.

Some hypertensive cardiovascular disease has been attributed to excessive consumption of sodium (usually as sodium chloride).[17] Since workers in the potash industry undoubtedly inhale and ingest some sodium and potassium as a result of handling and processing the potash ores, it seemed appropriate to examine deaths due to cardiovascular

Table 2. — Expected and Observed Nonmotor Vehicle Accidents* as Related to Work Experience

Work Area	Years of Potash Work Experience							
	1-4		5-14		≥ 15		TOTALS	
	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.
Surface	3.89	3	3.89	5	1.28	4	8.58	12
Underground	7.22	28†	5.84	14†	1.85	1	13.91	43†

* 1967 Accidents: includes all violent deaths except homicide, suicides and motor vehicle accidents.
† Significantly different from expected at 5% level.

Table 3. — % Distribution of Potash Industry Employees According to Work Area and of U.S. Males by Current Smoking Status*

Current smoking Status	Potash Industry Work Area				U.S. Males*
	Underground	Surface	Mixed	Totals	
Non-cigarette smokers	29.8	33.7	38.2	33.8	44.1
Cigarette Smokers					
1 pack cigarettes per day	40.4	38.6	37.2	38.8	40.2
1 pack cigarettes per day	29.8	27.7	24.6	27.4	15.8
	(n = 129)	(n = 113)	(n = 75)		

* Adjusted to the age of potash workers

disease among potash workers. The fact that no excess of deaths occurs in diseases of the heart, or vascular disease of the central nervous system suggests that the exposures to sodium and potassium salts incurred by potash workers has had little or no effect on mortality from cardiovascular disease.

The excess of accidental deaths among underground workers with short work experience is noteworthy. It has long been suspected, but not documented, that new underground miners have an increased work-related accidental death rate in contrast to more experienced miners. The data in Table 2 show this relationship for underground miners, but not for surface workers. Fifty-seven percent of the 42 accidents experienced by the underground cohort with less than 15 years of experience were due to accidents which occurred while at work. This is attributed to their lack of awareness of mine hazards, unfamiliarity with mine equipment, and lack of adherence to safe work practices.

Without the high number of nonmotor vehicle accidents, the total number of deaths observed for both cohorts combined would be significantly less ($p < 0.05$) than expected; 378 observed vs. 453 expected. This type of deficit is not uncommon for working populations. It is usually due to a combination of self-selection and preemployment screening.

In a preliminary analysis of this group of potash workers, there appeared to be an excess of respiratory cancer among both surface and underground workers.[6] The excess was attributed to the greater-than-usual cigarette smoking of the potash workers when compared to all United States males.[18] (Table 3). That analysis was based on incomplete death information and was analyzed by a proportionate mortality ratio method, in which violent deaths and non-malignant respiratory deaths were deleted from the denominator. The data in Table 1 indicate that the violent deaths account for a much higher percentage of deaths in the potash cohorts than in the United States as a whole. Thus deleting them from the denominator tended to inflate the proportionate mortality ratio for most other causes of death among potash workers. In addition, few of the additional deaths located since that analysis were of malignant disease. They were predominantly accidental and cardiovascular deaths, thereby altering the ratios.

One of the potash mines has used diesel engines as the major energy source for underground transportation since 1949, another since 1957. To ex-

plore the possibility of effects of exposure to diesel exhaust on mortality, the underground potash cohort was subdivided on the basis of which men had worked (and when) in these two mines and the life table method was again used to determine expected deaths. There were 31 deaths in 6733 person years. Except for violent deaths, no major cause of death exceeded expectation among men who had worked in the diesel using mines. No causes of death were significantly different between miners who worked in dieselized mines and those who worked in other mines. It may be noteworthy that the "other respiratory disease" category which was high among underground workers was not different between diesel and non-diesel workers. However, there may have been insufficient elapsed time since the start of diesel usage for chronic or long latent period diseases, such as emphysema or lung cancer, to be manifested as excess deaths in the relatively small exposed group.

Conclusions

There is no evidence of predisposition of underground miners to lung cancer or to any of the diseases evaluated. Secondly, there is no reason to believe that the underground environment increases respiratory disease when known noxious agents such as pneumoconiosis producing dust or radon decay products are absent or present in only minute amounts. The inverse relationship between "on the job" fatal accidents and duration of employment for underground miners indicates the importance of intense employee education in the area of safe work practices and adherence to those practices.

Exposure to sodium and potassium dust in the potash industry did not influence mortality due to heart disease or cerebrovascular accidents. No excess mortality was attributable to the presence of diesel engines in some mines; however, there has probably been too little elapsed time since introduction of the diesel engines for this observation to be definitive. A deficit of deaths from cancers other than respiratory among the surface workers could not be explained.

The authors express their indebtedness to Mr. Carl R. Jensen, Mr. Clayton M. Phelan, and Mrs. Isabel Nelson for their assistance in data collection, to the University of Utah Computer Center staff for programming assistance, and to the eight potash mining companies for their active cooperation.

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