RETROSPECTIVE MORTALITY STUDY OF OIL SHALE WORKERS, 1948-1977

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ABSTRACT

A cohort of 713 workers, employed in the oil shale industry between 1948 and 1969, were examined in a retrospective mortality study. These workers were primarily employed at the Anvil Points Oil Shale Facility near Rifle, Colorado, with a small group having been employed at the Union Oil Retort Facility at Grand Valley, Colorado. Of this cohort, 205 men were found to be deceased. Death certificates were available for 181 men, leaving a balance of 24 known dead without certificates. Analyses were done on 47 separate causes of death.

Based on the Standard Mortality Ratios obtained using Colorado-Utah white males as controls, this sample was found to have lower ratios than might be expected. We did, however, find significantly increased deaths due to malignant neoplasms of the colon and respiratory system. Oil shale work was sporadic and many of this group were smokers or ex-smokers and also had worked intermittently in uranium, vanadium, and other mining, which is also done in the area. A case control study to examine smoking and other mining exposures was done and it confirmed risks associated with smoking and radioactive exposure in persons dying of malignancies.

Those employed in the mining phase of oil shale work had the lowest mortality ratios for selected causes, while those employed in maintenance had the highest. Retorting and miscellaneous workers had mortality ratios that were intermediate in value. It is concluded that oil shale workers' mortality rates are lower than the regional control population, with the possible exception of increased rates of colon and respiratory malignancies.

INTRODUCTION

As oil shale activity increases on the Colorado plateau, it is important to examine the adverse health effects, if any, on workers exposed to either the oil shale or the kerogen which is retorted from the oil shale. At present, the number of persons who have been exposed to shale oil in occupations related to pilot scale retorting and laboratory work is limited. To date there have been no commercial scale operations, but Occidental Oil Shale, Inc., is currently sinking shafts for a commercial scale modified "in situ" operation on leased land northwest of Rifle, Colorado (1). Facilities capable of handling up to 50,000 barrels of shale oil per day are being developed by Rio Blanco Oil Shale Company (2). These plants are expected to be operating near capacity during the 1990's. As oil prices rise, shale oil becomes more attractive. If the currently planned facilities prove feasible, an increase in the number of retorting facilities may be expected.

METHODS

At the start of the mortality study, the universe from which the sample was drawn was estimated to be about 800 persons. The basis for this list was three employee groups: (a) 294 employees of the U.S. Bureau of Mines who worked at the Anvil Points Oil Shale Facility near Rifle, Colorado from 1948 to 1956; (b) 135 employees who worked at the Anvil Points facility from 1966 to 1969 for the joint venture of the Colorado School of Mines Research Institute and COLONY (a 6-company consortium); and (c) 15 men who worked from 1956 to 1959 at the Union Oil Retort Facility at Grand Valley, Colorado. Leads to other workers in these three groups that were not on our list came from the known members of the above groups and resulted in a master list of 1,215. The final cohort was a non-random sample containing 713 white males who worked in mining, retorting, maintenance, or supervisory jobs involving actual production of shale oil. Clerical workers, short-time (less than one month) personnel, and employees for whom we had only names and no other data were excluded in the final cohort. Of the 713 men, complete records were available for only 326 living persons, who underwent examination as part of a NIOSH morbidity study in 1977-78. Table 1 gives a breakdown of the cohort by vital status.

TABLE 1

FINAL COHORT

STATUS		NUMBER OF MEN
KNOWN LIVING		485
Examined 1977-1978	326	
KNOWN DEAD		205
Death Certificates	181	
No Death Certificate	24	
VITAL STATUS UNKNOWN		23
TOTAL		713

An oil shale worker was determined to be deceased if his death certificate was on file at the appropriate state agency of vital statistics, a claim had been made for death benefits, or other benefits had been terminated because of death. We considered a worker, for the purposes of this study, to be living if he had paid income tax after January 1, 1978, if a death certificate dated after 1977 was found, or if we had a valid address with no indications of death from state death indexes, beneficiary, or death claim files. Workers not meeting the above conditions for living or deceased were considered lost to follow-up. There were 23 men in this category and they were added to the list as presumed to be still living. A total of 205 men were deceased, on which we obtained 181 death certificates. Copies of death certificates were obtained and coded by a trained nosologist using the Eighth Edition of the International Classification of Diseases (3).

Two standard populations were chosen for this cohort using the years 1968, 1969, and 1970 to calculate average expected death rates. The first comparison population consisted of all white males in the states of Colorado and Utah. The second standard population consisted of all white males in the United States. It was used only to calculate expected deaths due to all causes. The number of observed deaths was tabulated for each group or subgroup for the study period. Death rates for diseases are expressed as standard mortality ratios (SMR's). That is, the ratio of observed deaths to expected deaths times 100. Expected deaths were determined using a modified life table procedure (4). A correction was made in the denominator to take into account the 24 deaths that were not covered by death certificates. SMR's were checked for a statistically significant departure from 100 by use of the Chi Square statistic (5). One word of caution should be mentioned. Death rates for specific causes may change over time. For example, death rates for lung cancer have increased over the past several years while death rates for digestive cancer have decreased. Since our standard population involves an average of only three years, this may cause the resulting SMR's to underestimate or over-estimate risk for a specific disease.

RESULTS

Before looking at causes of death, it is most important to look at the smoking pattern of the cohort. Unfortunately, smoking histories were available on only 378 or 53 percent of the men. Table 2 divides this subgroup into smokers, ex-smokers, and nonsmokers. Smokers and ex-smokers account for 307 of the 378 men or 81.2% of this group. However, the value of 37.8% for smokers is a low prevalence for smokers in an industrial population. Correspondingly, 43.4% is high for ex-smokers. (See Discussion.)

TABLE 2

OIL SHALE SMOKING ACTIVITY

	NUMBER	PERCENT
SMOKERS	143	37.8
EX-SMOKERS	164	43.4
NONSMOKERS	71	18.8
	378	

SMOKERS + EX-SMOKERS = 307 or 81.2%

Table 3 is a listing of the SMR's for all causes and 13 specific causes of death utilizing Colorado and Utah white males as controls. The SMR for All Causes using the U.S. white males as controls is also shown. Colorado and Utah have similar average lifetimes for white males; 68.53 years for Colorado and 69.54 for Utah. Both are greater than the U.S. which is 67.94 years (6). Several items on this listing are of interest. Deaths due to All Causes show a reduced SMR regardless of which control population is used. This may be a consequence of the "healthy worker effect" and is a characteristic of working populations. In the case of the U.S. control, this decrease is statistically significant at the 1% level.

TABLE 3

GENERAL SMR's
OIL SHALE STUDIES

	OBSERVED	EXPECTED	SMR
U.S. CONTROL			
All Causes	205	245.76	83.4**
COLORADO & UTAH CONTROL			
All Causes	205	220.89	92.8
All Malignant Neoplasms	49	35.72	137.2*
Buccal Cavity and Pharynx	1	1.19	84.0
Digestive Organs & Peritoneum	15	9.53	157.4
Stomach	2	1.72	116.3
Colon	7	3.10	225.8*
Respiratory Organs	16	10.88	147.1
Trachea, Bronchus & Lung	16	10.25	156.1
Genital Organs	2	2.43	82.3
Urinary Organs	2	2.38	84.0
Benign & Unspecified Neoplasms	0	0.66	--
Diseases of Circulatory System	76	101.53	74.9**
Ischemic Heart Diseases	55	72.45	75.9*
Diseases of Respiratory System	18	17.88	100.7
Accidents	18	15.29	117.7

* Significant at 5% level.
** Significant at 1% level.

The SMR for all malignant neoplasms shows a statistically significant excess of deaths primarily due to colon cancer and cancer of the trachea, bronchus, and lung. Diseases of the circulatory system have a SMR of 74.9 which exhibits a highly significant deficit of deaths with ischemic heart disease showing a significant deficit, rheumatic heart disease having an increase of deaths, and all other forms of heart disease having a highly significant deficit of deaths. For diseases of the respiratory system, the SMR is 100.7 which shows no difference from the control population. Various items under this general heading show increases and decreases. Under the heading of accidents, an increased SMR is shown but the increase is not statistically significant.

TABLE 4

JOB ACTIVITY WITHIN OPERATING STAFF

CAUSE	MINING SMR	RETORTING SMR	MAINT SMR	MISC. SMR
All Causes	71.7	133.5	101.0	88.6
Malignant Neoplasms	49.8	89.6	149.9	138.9
Major Cardiovascular Diseases	56.3	182.5	73.9*	68.0
Diseases of Respiratory System	108.6	97.1	119.9	164.9
Accidents	151.6	84.2	157.2	67.4

MINING	= 105
RETORTING	= 60
MAINTENANCE	= 311
MISCELLANEOUS	= 68

Underlined values have less than five observed.

* Significant at 5% level.

Employment in the oil shale industry has been erratic and lengths of employment have varied from weeks to months. Length of employment is skewed towards short-term employment with a median of 9 months and an average of approximately 30 months. Over 50% of the workers have 2 years or less employment in oil shale work.

Operating jobs, meaning those that required exposure to mining and retorting of the shale, were divided into the following four categories: mining, retorting, maintenance, and miscellaneous. Table 4 shows the SMR's (Colorado and Utah controls) for each of the four job categories by 5 broad causes of death. Deaths due to all causes showed deficits in mining and miscellaneous, normal in maintenance, and excesses in retorting. Deaths from malignant neoplasms showed deficits in mining and retorting and excesses in maintenance and miscellaneous workers. Major cardiovascular disease deaths were low in all categories with the exception of retorting. Deaths from diseases of the respiratory system were about normal in the mining and retorting groups, slightly increased for the maintenance people, and moderately increased for the miscellaneous group. Accidental deaths were greatest in the mining and maintenance areas and lowest in the retorting and miscellaneous groups.

CASE CONTROL STUDY

In an attempt to clarify the effects of certain risk factors, namely smoking, radioactive exposure and metal mining exposure, a case control study of 27 oil shale workers dying from respiratory cancer and digestive cancer was done. Two separate control groups were used for this study. The first control group was made up of 27 oil shale workers that had died from diseases of the circulatory system, ICDA 390-458. This group was picked because it contained enough people to allow for matching. The second control group was made up of 27 living oil shale workers. Workers were matched as closely as possible on the basis of age, job classification, and length of service in that job. Odds ratios were calculated by the method by Guy (7). Results are given in Table 5.

In reference to lung cancer, we have elevated odds ratios for radioactive exposure in the study group versus both control groups, 7.1 against the deceased group and 7.9 against the living group. There is also an elevated ratio of 11.0 for smoking against the living group. Unsurprisingly, the odds ratio is 1.1 for smoking against the deceased group.

TABLE 5

ODDS RATIOS

CAUSE OF DEATH	EXPOSURE	STATUS	STUDY GROUP	DECEASED CONTROL	LIVING CONTROL	DECEASED ODDS	LIVING ODDS
LUNG CANCER	SMOKING	YES	11	10	6	1.1	11.0
		NO	1	1	6		
	RADIOACTIVITY	YES	5	1	1	7.1	7.9
		NO	7	10	11		
	METAL MINING	YES	2	5	2	0.3	1.3
		NO	8	6	10		
DIGESTIVE CANCER	SMOKING	YES	9	11	2	0.4	9.8
		NO	6	3	13		
	RADIOACTIVITY	YES	5	1	3	7.2	2.2
		NO	9	13	12		
	METAL MINING	YES	1	1	0	1.1	---
		NO	12	13	15		

$$\text{ODDS RATIO} = \frac{ad}{bc}$$

Where: a = number of yes answers in the study group
b = number of no answers in study group
c = number of yes answers in control group
d = number of no answers in control group

As smoking is suspected as being associated with various diseases of the circulatory system (8), there would be competition by both lung cancer and circulatory system disease with the end result being a depressed odds ratio for smoking. Metal mining exposure has no effect on lung cancer in this case control study.

A similar situation exists when one looks at digestive cancer. Again, we see elevated odds ratios due to radioactive exposure except that while both ratios are elevated, the ratio using the deceased control group is much higher, 7.2 versus 2.2. As we are concerned with relatively small numbers, an increase of two people makes a large change in the results. Smoking shows an elevated odds ratio for digestive cancer in the living control group of 9.8 and a depressed odds ratio of 0.4 in the deceased control group. As smoking is known to be associated with circulatory disease deaths (see above reference) and since the cause of death for the deceased population was circulatory system problems, the low odds ratio in this control group is expected. Metal mining exposure seems to have little influence as far as digestive cancer is concerned.

DISCUSSION

In our current study we found some interesting results that warrant further discussion. The SMR's for all causes of death were 83.4** for the U.S. control population and 92.8 for the Colorado-Utah population. This is suggestive of the "healthy worker effect" as described by McMichael (9) and demonstrated by Ortmeyer (4). As further evidence of this, the SMR for diseases of the circulatory system was 74.9** which is highly significant. Because work in this industry involves a lot of physical activity both indoors and outdoors, a low SMR for cardiovascular diseases is not unexpected.

One general area in which an increase of deaths was indicated was that of all malignant neoplasms. The SMR for this broad category was 137.2 which is statistically significant at the 5% level. A closer look at this shows that this increase is primarily caused by excess deaths of digestive cancer, primarily colon cancer, and cancer of the trachea, bronchus, and lungs. In addition to occupational exposure, there are several other potential risk factors. The first of these risk factors is smoking. As indicated in the Results section, the percentage of smokers and ex-smokers for which we have data amounts to 81.2%.

If one looks at other industrial groups, Ortmeyer (4), Costello (10), and Gamble (11), this proportion is within reason. However, the percentage of smokers in the oil shale cohort, 37.8% is very low. Values from the above referenced studies for smokers run from a low of 49% in talc workers in Montana (Gamble) to 75% in metal miners (Costello). The death rate for lung cancer in all males for 1977 was 22.89/100,000 in Utah*** and 36.06/100,000 in Colorado.**** In order to confirm the effect of smoking, attempts were made to locate families of persons dying from either respiratory or digestive cancer. We were successful in contacting 12 of 16 families of workers who died from lung cancer. Ten of the 12 workers were smokers and one was a probable smoker. In addition, our case control study showed a greatly increased odds ratio of 11.0 for smoking when the study group was compared to the living control group in which there was no known disease that was associated with smoking and a ratio of 1.1 in the case of a control group in which people died from a disease associated with smoking. In the case of persons dying from digestive cancer, we were able to locate 15 families out of a total of 15. Nine workers smoked, one chewed, and the rest were nonsmokers. Again, the case control study showed an increased odds ratio of 9.8 for smoking when compared to the living control group. The deceased control group showed a depressed odds ratio of 0.4.

A second risk factor that is involved is exposure to radioactive materials. We know that 70 people of the 326 men for whom we have complete job histories had worked in uranium and vanadium mines and mills. In addition, 21 of the deceased workers had similar experience.

**Statistically significant at 1% level.

*** Utah State Department of Health, Division of Vital Statistics.

**** Colorado Department of Health, Records and Statistics Section.

The number of people in the rest of the cohort that have had this experience is unknown.

As part of the inquiry on smoking in oil shale workers dying from respiratory and digestive cancer, it was found that 6 of 12 workers dying from lung cancer had worked in uranium and vanadium mines or mills. In the case of digestive cancer, 5 of 15 workers had worked in uranium and vanadium mines or mills. Lundin, Archer, et al (12) have reported a strong association between radioactivity and lung cancer. Referring to our case control study, we found that radioactive exposure in the study group, such as working in uranium and/or vanadium mines and mills, resulted in increased odds ratios against both control groups in both types of cancer under discussion. The odds ratios in the case of lung cancer were 7.1 using deceased controls and 7.9 using living controls. The values for digestive cancer are 7.2 and 2.2 respectively. These findings support the hypothesis that the elevated SMR's for lung and digestive cancer were due to smoking and uranium mining.

Another possible risk factor is that of working in metal mines other than those which are classified as being radioactive. This was examined in the case control study with the result that metal mining exposure seems to have little or no effect on lung or digestive cancer death odds ratios, which varied from none to a high of 1.3.

A fourth variable to consider is background radiation. The National Academy of Science (13) has recently reported that the Colorado Plateau has the highest background radiation in the country. The Academy council reported that this low level radiation was more likely to cause cancers of the thyroid, lung, digestive system, and breast than other types of cancers.

A fifth item to consider is that the SMR's of mining workers and retort workers showed deficits for malignant neoplasms. In 1975, LFE Corporation did an industrial hygiene survey of the Paraho Oil Shale Mining and Processing Facility at Anvil Points, Colorado (14). In the mining operation, measurements were taken for respirable dust, coal tar volatiles, NO_2, NO, SO_3 as H_2SO_4, and formaldehyde. None of the results indicated contaminant concentrations exceeding the standards in effect at that time. The pay loader operator appeared to get the highest exposure to diesel effluents as he backed away from the face. In aboveground operations, the process of retorting contains the contaminants inside a closed system. LFE reported low fugitive emissions in the work environment during normal operation. It should be pointed out that in operations such as pilot plants, normal operations are generally the exception. Their results indicated no concentration exceeded existing standards.

One last point to be made concerns job activity. If we look at job groups across the various causes, it is apparent that the maintenance group has more excess deaths than deficits. This would be expected as maintenance men tend to have to work in poorly ventilated places which tend to be dusty and dirty. The mining group has the most deficits with the exception of accidents. It should be pointed out that diesel powered equipment (trucks, payloader, jumbo drill, roof bolter, and platform truck) are used underground in the mining operation. The SMR for malignant neoplasms are low in this group. Retorting and miscellaneous people were between the mining and maintenance in number of deficits and excesses.

In light of the several other carcinogenic risk factors, including cigarette smoking, exposure to radiation, metal mining, and diesel exposure, as well as the pattern of mortality by job classifications, it is difficult to implicate oil shale exposure per se as responsible for the increase in SMR for respiratory cancer and digestive cancer.

It is apparent from the results of the case control study of oil shale workers that radioactive exposure is associated with deaths caused by respiratory cancer and cancer of the digestive system. In addition, smoking was associated with an increased odds ratios for both types of cancer against the living controls. Metal mining exposure was not associated with changes in odds ratios for either disease.

Although elevated SMR's for malignant neoplasms were found, they appear to be most strongly associated with smoking and exposure to radiation in this cohort. It must, however, be appreciated that the exposure to shale oil, which has been shown to be carcinogenic in humans (15,16,17), was brief.

Therefore it is important to maintain active surveillance on this cohort and others exposed to oil shale mining and processing.

CONCLUSIONS

Standard Mortality Ratios were calculated for a cohort of 713 oil shale workers who were primarily employed at the U.S. Bureau of Mines Anvil Points Oil Shale Facility near Rifle, Colorado, from 1947 through 1969. The following conclusions were generated from the data that was analyzed:

1) This cohort appears to exhibit the "healthy worker effect". With one major exception, noted below, the SMR's for major disease classifications have either been at less than normal or at approximately normal levels.

2) Members of the cohort show decreased deaths for all causes and for diseases of the circulatory system including ischemic heart disease. They show no difference in SMR for diseases of the respiratory system and a slight, but not significant increase for accidents.

3) This cohort shows a significant increase of malignant neoplasms particularly for the colon and less so for cancer of the trachea, bronchus, and lung. In light of the several other carcinogenic risk factors previously mentioned and investigated in the case control study, it is difficult to implicate oil shale exposure per se as responsible for the increase in SMR for respiratory cancer and digestive cancer. The case control study indicates a stronger association between these cancers and exposure to radioactivity and smoking than with exposure to oil shale.

4) Maintenance workers tended to have the highest SMR's and mining workers had the lowest SMR's.

5) Surveillance of oil shale workers for health effects in the future is high priority.

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