SYMPOSIUM ON CHARACTERIZATION AND CHEMISTRY OF OIL SHALES
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# MORTALITY, MORBIDITY AND OTHER NIOSH HEALTH RELATED STUDIES OF OIL SHALE WORKERS

By

J. Costello
Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health
Morgantown, West Virginia 26505

## INTRODUCTION

At the time of the conception of the NIOSH shale oil studies, oil prices were going up and there was renewed interest in synfuels, especially shale oil. Originally, most of oil shale extraction work was done on a demonstration project basis with a small work force (1). Then Union Oil Company of California and the COLONY project (2) of TOSCO and Exxon began commercial scale projects in shale oil production on the Colorado plateau. With an unfavorable change in the business climate, the Colony project was dropped and the Union Oil Company project was delayed. Union is now expected to go into production shortly. Thus, health considerations of exposure to kerogen become important. Three completed NIOSH studies involving this synfuel will be discussed. These include a mortality study, a case-control study and a morbidity study. In addition, two new studies involving shale oil will be presented.

## METHODS

The first study to be done was the mortality study (3). The universe from which the sample was drawn was estimated to be about 800 people. 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; and c) 15 men who worked from 1956 to 1959 at the Union Oil Retort Facility at Grand Valley, Colorado. Leads to additional workers in these groups resulted in a master list of 1215. From this master group, a non-random sample consisting of 713 white males who worked in mining, retorting, maintenance or supervisory jobs involving actual production of shale oil was chosen for mortality follow-up. Clerical workers, short-term (less than one month) personnel and employees for whom we had only names and no other data were excluded from the final cohort. Of the 485 living subjects of this cohort, 321 men and 4 women were examined in the morbidity study. Table I gives the breakdown of the 713 subjects by vital status.

TABLE I

FINAL COHORT

| | In Morbidity Study | In Mortality Study |
|---|---|---|
| Known living | 325 | 485 |
| Known deceased | | 205 |
| (a) Death certificates | | (181) |
| (b) No death certificates | | (24) |
| Vital status unknown | | 23 |
| Grand Totals | 325 | 713 |

### Mortality

Standard populations for determining expected deaths were: (a) all white males in the states of Colorado and Utah, and (b) all white males in the United States. Mortality statistics were averaged for the years 1968, 1969 and 1970 to calculate expected death rates. The U.S. population was used only for all causes to check for the "healthy worker effect". Standardized Mortality

Ratios (SMR) were calculated using a modified life table procedure. Death certificates were coded by a nosologist utilizing the Eighth Revision International Classification of Diseases Adopted for Use in the United States (4).

Case-Control

During the course of the mortality study, it was determined that 16 men died of cancer of the trachea, bronchus and lungs, and 15 men died of cancer of the digestive organs and peritoneum. In an attempt to clarify the effects of certain risk factors, namely smoking, radioactive exposure and metal mining exposure, a case-control study of 12 oil shale workers dying from respiratory cancer and 15 workers dying from digestive cancer was done. Two separate control groups were used: the first was composed of 27 oil shale workers who had died from diseases of the circulatory system and the second was composed 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 of Guy (5).

Morbidity

The third study, the morbidity study, was related to the mortality study in that the 485 known living survivors from the mortality study formed the basis for the morbidity study. 321 men and 4 women agreed to participate, for a participation rate of 67%. The balance of 160 workers were untraceable, had moved to distant points that were too costly to visit, or declined to participate. Coal miners at 3 Utah mines were used for comparison because they worked on the Colorado plateau, did not work with oil shale materials, were readily available and could be matched by age. However, they were exposed to coal mine dust, a well documented cause of respiratory symptoms. We considered other sources of controls in the region such as uranium miners, smelter workers, metal miners, etc., but rejected them because of confounding cancer risks which was our primary objective to evaluate among the oil shale workers. Thus, it was felt that coal miners were the best of a poor choice for the control population. Each worker was questioned about his work history, smoking history and information on medical problems and respiratory symptoms, the respiratory symptoms are to be reported in a separate paper later. A complete dermatological examination was given by certified dermatologists and sputum and urine cytologies were done. Only results of skin examination, sputum and urine cytologies will be reported here.

## RESULTS

Mortality Study

Table II presents a listing of the SMR's for all causes and several specific causes of death utilizing Colorado-Utah white males as controls. We also show an SMR for all causes using all U.S. males as a control. Statistically significant increases in SMR's are seen for all malignant neoplasms and cancer of the colon. Nonstatistically significant increases are seen for cancer of digestive organs and peritoneum, cancer of respiratory organs and cancer of the trachea, bronchus and lungs. Statistically significant decreases are seen for all causes (U.S. control), diseases of the circulatory system and ischemic heart disease. The significant decrease in all causes may be a consequence of the "healthy worker effect" and is a common characteristic of working populations (6).

Smoking is always an item of interest when increased SMR's for respiratory and lung cancer are seen. Table III presents a summary of the smoking history data that was available for this cohort. Unfortunately, these data were only available for 325 living workers and 53 deceased workers. 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 (7).

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 arithmetic average of approximately 30 months. Over 50% of the workers have 2 years or less employment in oil shale work. This limits the implications of oil shale exposure as a causative agent in the development of chronic disease.

Case-Control Study

Table IV is a breakdown of the various categories of smoking by disease. It is quite apparent that smoking is an important factor in lung cancer. Smokers account for all but one case of lung cancer in both the case group and the deceased control group. In digestive cancer, smokers account for the majority in both the case group and the deceased control group.

The results of the case control study are numerically illustrated in Table V. Looking at the results for lung cancer, we see elevated odds ratios for radioactive exposure in the study group versus both control groups. The values are 7.9 using the living control. We also see an elevated odds ratio for smoking using the living control. Unsurprisingly, the odds ratio is 1.1 for smoking using the deceased 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 was not related to lung cancer in this case control study.

TABLE II

STANDARDIZED MORTALITY RATIOS

| Cause of Death | Observed | Expected | SMR |
|---|---|---|---|
| All causes (U.S. control) | 205 | 246 | 83[b] |
| All causes (CO and UT control) | 205 | 221 | 93 |
| All malignant neoplasms | 49 | 36 | 136[a] |
| Digestive Organs and Peritoneum | 15 | 10 | 150 |
| Colon | 7 | 3.1 | 226[a] |
| Respiratory Organs | 16 | 11 | 145 |
| Trachea, bronchus and lung | 16 | 10 | 160 |
| Diseases of circulatory system | 76 | 102 | 75[b] |
| Ischemic heart diseases | 55 | 72 | 76[a] |
| Diseases of respiratory system | 18 | 18 | 100 |
| Accidents | 18 | 15 | 120 |

a. Statistically significant, p .05
b. Statistically significant, p .01

TABLE III

SMOKING DATA

MORBIDITY COHORT + CASE CONTROL COHORT

| Smoking Status | Number | Percent |
|---|---|---|
| Ex-smokers | 164 | 43.4 |
| Smokers | 143 | 37.8 |
| Nonsmokers | 71 | 18.8 |
| Total | 378 | 100.0 |

Smokers + Ex-Smokers = 307 or 81.2%

TABLE IV

SMOKING

CASE CONTROL STUDY

| Disease | Category | Case | Living Control | Deceased Control |
|---|---|---|---|---|
| Lung cancer | Smokers | 11 | 6 | 10 |
| | Ex- and nonsmokers | 1 | 6 | 1 |
| Digestive cancer | Smokers | 9 | 2 | 11 |
| | Ex- and nonsmokers | 6 | 13 | 3 |

A similar situation exists for 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.

TABLE V

ODDS RATIO

CASE CONTROL STUDY

| Cause of Death | Exposure | Odds Ratio: Living Controls | Odds Ratio: Deceased Controls |
|---|---|---|---|
| Lung cancer | Smoking | 11.0 | 1.1 |
| | Radioactivity | 7.9 | 7.1 |
| | Metal Mining | 1.3 | 0.3 |
| Digestive cancer | Smoking | 9.8 | 0.4 |
| | Radioactivity | 2.2 | 7.2 |
| | Metal Mining | - | 1.1 |

In summary, the case-control study suggests that smoking and radioactive exposure have stronger association with lung and digestive cancers than does oil shale exposure in this population.

Morbidity Study

Table VI presents a brief summary of important presumed risk factors in the morbidity study. Although the study group and the control group are well matched for age, the oil shale workers had worked more time in other oil work, uranium mining and farming. In addition, the oil shale workers had spent more of their working time outdoors than the controls. Fewer of the oil shale workers were current smokers but despite this, their pack years were considerably greater. These imbalances of risk factors, coupled with the short duration of exposure to oil shale, make interpretation difficult.

TABLE VI

AGE, SMOKING, OCCUPATION AND OTHER VARIABLES FOR THE OIL SHALE AND CONTROL GROUPS

| | Oil Shale | Control |
|---|---|---|
| Number | 325 | 323 |
| Mean age (years) | 56 | 56 |
| % current smokers | 28 | 37 |
| Mean pack years | 35 | 27 |
| Mean years in oil shale work | 6.0 | 0 |
| Mean years in oil shale production work | 2.9 | 0 |
| Mean years in other oil work | 1.3 | 0.1 |
| Mean years in uranium mining | 1.9 | 0.2 |
| Mean years in other mining | 2.0 | 29.8 |
| Mean years in farming | 3.4 | 2.5 |
| Mean percentage of time spent at work out of doors over last 20 years | 47 | 23 |
| Mean percentage of time spent off duty out of doors over last 20 years | 58 | 51 |

The mean of 6 years conceals a rather skewed distribution of work in oil shale; 50% of the oil shale group had worked less than 4 years. For work in oil shale production, the figures were 2.9 years for the mean and 1.3 for the median, with 90% having worked less than 8.4 years.

Sixteen men in each of the study group and control group were suspected as having one or more tumors. Most of the suspected tumors were biopsied; eight basal cell and two squamous cell carcinomas were found in the oil shale group. The latter four tumors were on the nose, face, neck and finger, respectively. The corresponding exposures for these four men were: two years as office manager in oil shale for the first; two years in oil shale as miner and foreman, but 19 years in uranium mining for the second; three years in oil shale as powderman and carpenter, but nine years processing uranium and vanadium plus 38 years in ranching for the third; and four years in oil shale in mechanical design for the latter.

The results of the dermatological examinations are shown in Table VII. Oil shale workers have a higher mean number per person of pigment changes and keratoses and a higher percentage of persons having nevi and keratoses. The control population has a higher mean per person of nevi, telangiectasiae and papillomata and a higher percentage of persons having pigment changes, telangiectasiae and papillomata.

TABLE VII

SUMMARY STATISTICS OF DERMATOLOGICAL EXAMINATION FINDINGS

| | Mean Number Per Person | | Percentage with Entity | |
|---|---|---|---|---|
| Entity | Oil Shale | Control | Oil Shale | Control |
| Nevi | 4.3 | 5.4 | 77 | 64 |
| Pigment change | 0.8 | 0.7 | 31 | 34 |
| Telangiectasiae | 18.5 | 22.0 | 80 | 83 |
| Keratoses | 3.0 | 1.9 | 43 | 37 |
| Papillomata | 1.7 | 1.9 | 45 | 47 |

A logistic regression model showed a significantly increased prevalence of actinic keratoses associated with oil shale exposure ($p < 0.01$). However, hyperpigmentation did not show a significant trend with oil shale exposure. As one would expect, both age and sun exposure were also significantly correlated with the presence of actinic keratoses; papillomata were correlated with age and both pigment changes and telangiectasiae were correlated with sun exposure. Leukoplakia was noted on the lips and oral mucous membranes of 10 oil shale workers and 14 controls. Table VIII presents the cytology findings for controls and oil shale workers by smoking group. Among smokers, the oil shale group had a higher proportion with metaplasia than the controls. This did not constitute a statistically significant difference, however, ($\chi^2 = 2.48$). Correction for age and pack years did not reduce the observed disproportion to any great extent. The ex-smokers showed a similar tendency to have a higher rate of metaplasia while the nonsmokers revealed the opposite effect, though again nonsignificantly ( $\chi^2 = 0.58$). For dysplasia, both smokers and ex-smokers showed slight excesses among the oil shale workers but nonsmoking controls had about twice the prevalence as the oil shale group. Statistical significance was not achieved, however, ($\chi^2 = 1.98$).

TABLE VIII

PULMONARY CYTOLOGY BY SMOKING HABITS AND STUDY GROUP

| | Normal Cytology | | Metaplasia No Dysplasia | | Dysplasia | | n | |
|---|---|---|---|---|---|---|---|---|
| | Oil Shale | Control | Oil Shale | Control | Oil Shale | Control | Oil Shale | Control |
| Smokers | 40 | 51 | 34 | 24 | 26 | 25 | 88 | 105 |
| Ex-smokers | 45 | 51 | 31 | 26 | 24 | 23 | 143 | 117 |
| Nonsmokers | 68 | 53 | 22 | 28 | 10 | 19 | 58 | 67 |
| | | | | | | TOTALS | 289[a] | 289[b] |

a. Fewer than overall totals because of missing and unsatisfactory samples.
b. One additional control had an invasive malignancy.

A logistic model relating years of work in oil shale production to presence or absence of signs of metaplasia and dysplasia was fitted to the oil shale group, divided into current smokers and non-smokers. For metaplasia there was a positive relation with production work in both smoking groups ($p < 0.05$ for both) and the two coefficients were similar in magnitude. For dysplasia, both smoking groups showed a negative trend with years of exposure although these were both statistically significant. One rather strange result of these analyses is that age did not appear to be related to either metaplasia or dysplasia. In addition, pack years was not significantly associated with these two factors among the smokers.

In summary, actinic keratoses showed a significant and positive association with oil shale exposure after allowing for age, sunlight and other exposures. In addition, the prevalence of metaplasia was positively associated with years of oil shale production work.

## NEW PROJECTS

NIOSH is currently involved in two new oil shale projects, a feasibility study of community-based occupational health registry of oil shale workers and an extension of a DOE mortality contract with the Institute of Occupational Medicine in Edinburgh, Scotland to identify survivors of Scottish Oils Ltd. for the determination of the prevalences of shale workers pneumoconiosis and skin tumors. This second project will also look at mineralogical characterizations and documentation of the mining and retorting processes utilized in the Scottish shale industry.

The feasibility study of a community-based registry has been awarded to the National Jewish Hospital and Research Center in Denver. With this contract, we hope to accomplish the following work:

1. Abstract medical records of cases of cancer diagnosed in the period 1979 through 1981 in the counties in planning region XI -- Garfield, Rio Blanco, Mesa and Moffat Counties. This information will be offered to the Colorado State Tumor Registry.

2. Design and initiate a protocol for pulmonary function studies and questionnaire data from oil shale workers and appropriate controls, which can be used as base line data toward a future registry. The design will address the need for longitudinal study of workers and controls, especially with regard to quality assurance and research needs for early detection of respiratory hazards in the industry. Stability of personnel dictates the involvement of local medical facilities with collaboration of the Preventive Medicine Department of the University of Colorado Health Sciences Center. The outcome of this objective will depend, in part, on whether company cooperation is obtained, since the design of the study changes substantially if access to the workforce at the work site is not possible.

3. Assess the feasibility of a worker registry in the oil shale industry, in cooperation with currently active Western Slope oil shale companies or, independent of them, in a community-based effort. If coordination with industry-based efforts proves possible, means for such coordination will be developed. Data collection in the respiratory evaluation in item 2 will be evaluated for use in a community-based registry. Success and obstacles encountered in conducting pulmonary evaluation will be assessed for their implications for a long term registry of oil shale workers. A system of record keeping will be developed in an appropriate institution in Garfield County.

To date, item 1, the cancer case abstractions, have been completed and the data have been turned over to the Colorado State Cancer Registry. The Garfield County Health Officer, Dr. Mary Jo Jacobs, has been working on local funding to continue this work. Item 2, the design and initiation of a protocol for pulmonary function studies, is progressing well. Procedures and questionnaires have been developed and tried out on a group of molybdenum workers at Leadville, Colorado. Final revisions are in progress. Item 3, an industry-supported registry has suffered a setback because of the business recession and abandoning or backing off of companies interested in the developing of shale oil. The loss of the combined Exxon-TOSCO project was a big blow to shale oil development in general.

The Scottish project involves workers who formerly worked for Scottish Oils Ltd., a commercial producer of shale oil, until it shut down in the middle 1950's. The Institute of Occupational Medicine is currently involved in a mortality study of these workers for DOE. NIOSH recommended that a morbidity study of shale workers' pneumoconiosis and skin lesions be done on the survivor group of this cohort.

As of the writing of this report, 1605 men have agreed to participate in the dermatology portion of the study and 1324 of these men have agreed to have chest X-rays taken. Presently, 978 men have completed dermatology questionnaires and the first part of the chest X-ray survey involving 585 men has been completed. The study is to be completed by October 1, 1984.

## CONCLUSIONS

Standardized Mortality Ratios were calculated for a cohort of 713 oil shale workers who were employed primarily at the U.S. Bureau of Mines Anvil Points Oil Shale Facility at Rifle, Colorado, from 1947 through 1969. In addition, 325 living oil shale workers from the above cohort were examined in a morbidity study primarily aimed at dermatological changes. The following conclusions were generated from the data collected:

1. Oil shale workers appear to exhibit the "healthy worker effect". With one major exception, noted below, the SMR's for major disease classification have either been normal or less than normal.

2. Oil shale workers 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. Oil shale workers show 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. The prevalence of actinic keratoses was associated significantly and positively with oil shale work exposure after allowing for age, sunlight exposure and other exposures.

5. The prevalence of metaplasia was positively associated with years of production work in oil shale.

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