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Morbidity Survey of U.S. Oil Shale Workers Employed During 1948–1969

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ABSTRACT. The health status of 325 oil shale workers employed at the Anvil Points, Colorado, demonstration facility from 1948 to 1969 was evaluated. As a comparison population, 323 Utah coal miners frequency matched for age were studied. The prevalence of respiratory symptoms among oil shale workers who smoked were similar to the coal miners who smoked, although nonsmoking oil shale workers had fewer symptoms compared to nonsmoking coal workers. Four cases of skin cancers were found on the oil shale workers and eight cases in the controls. Similar numbers of nevi, telangiectasiae, possible pitch warts, pigment changes (solar/senile lentigo), and papillomata (seborrheic keratoses and skin tags) were seen in both groups, while actinic keratoses were more frequent in the oil shale workers. The prevalence of actinic keratoses was significantly associated with oil shale work after allowing for age, sun exposure, and other exposures. The prevalence of pulmonary cytology metaplasia was associated with years of production work in oil shale among both smokers and exsmokers. More of the oil shale workers had atypical cells in the urine, but the excess was mostly found among exsmokers. Although these workers had short-term and limited oil shale exposure work exposure, we recommend that medical surveillance of oil shale workers consider the skin, respiratory, and urinary systems for special observation.

OIL SHALE is an abundant resource in the United States with 600 billion barrels of potentially recoverable oil from the Green River formation using known technologies.[1] The extraction processes will include underground mining and surface retorting to shale oil, although a variety of methods, including in situ and modified in situ, are under active exploration. Workers may be exposed to a variety of materials with a range of toxicity: oil shale dust, gases, fumes, mists, catalysts, and shale oil. Skin cancers, including both squamous and basal cell carcinomas, have been reported by Scott[1] among early Scottish oil shale workers, and cancer of the scrotum was reported among "mule spinners" in the early English textile mills when refined oil shale was used

to lubricate spindels.[1-3] Furthermore, respiratory symptoms and pneumoconiosis have been found among some oil shale miners and workers in Scotland and Estonia.[1,4,5] Shale oil, when painted on the skin of mice, has also been found to be carcinogenic.[6]

An oil shale mine and surface retort was operated on a demonstration basis at Anvil Points near Rifle, Colorado, by the United States Bureau of Mines and Colorado School of Mines from 1948 to 1969. The facility consisted of a mine at 8,500 ft above sea level and an outside retort with attendant rock crushing equipment at approximately 6,500 ft. We identified, located, and examined as many former workers as possible of this facility who were employed during 1948–1969, plus a small cohort from the Union Oil Company retort facility near Grand Valley, Colorado, operating during the same time period. The purpose of our study was to evaluate these workers' skin for malignant changes, sputum and urine for cytology, and to administer questionnaries for respiratory symptoms and occupational history. We determined the prevalence rates of changes in their health status and compared them to another group similar in age and residence but without oil shale work experience.

METHODS

Study subjects. The subjects were selected from a previous National Institute for Occupational Safety and Health (NIOSH) mortality cohort of oil shale workers.[7] In that study, of 713 workers who were nearly all involved in mining, retorting, maintenance, or supervisory jobs involving actual production of oil shale, 485 workers were found to be living. Of this group, 321 men and 4 women agreed to participate in the morbidity study. The balance of 160 workers were untraceable, had moved to distant points that were too costly to visit, or were uninterested in participating. Examinations were conducted during 1978 and 1979.

Coal miners at three 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-known 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 comparison population.

Medical evaluations. Trained interviewers queried each subject regarding their chronological occupational history, smoking history, modified British MRC questionnaire on respiratory symptoms, and medical history.

Each participant was given a thorough dermatologic examination by one of two dermatologists (GK and JZ). The examination consisted of first noting hair and eye color, skin pigmentation, and amount of hair. The numbers and sites of telangiectasiae, actinic keratoses, papillomata (seborrheic keratoses and skin tags), suspected malignant tumors, nevi, possible pitch warts, and pigment changes were checked. The lips, tongue, and mucous membrane of the mouth were examined for leukoplakia. The two dermatologists met beforehand and agreed on definitions for the abnormalities listed above. Skin tumors that were suspected to be malignant were biopsied.

Sputum for cytology was collected by study personnel and examined by Geno Saccomanno, M.D., Ph.D., St. Mary's Hospital, Grand Junction, Colorado. Each participant expectorated into a wide-mouthed specimen bottle containing 50 ml of fixative, which consisted of 48 ml of 50% ethyl alcohol, 1 ml of 50% polyethylene glycol, and 1 ml of ethyl alcohol containing 3 mg of rifampin. The specimen was emptied into a blender and blended for 5 sec, followed by centrifugation at 1500 rpm for 15 min. The pellet was resuspended and 2 drops were applied to a glass slide, allowed to dry, and stained with Papanicolaous stain. A spot urine sample was collected and examined using the same technique at the Department of Pathology, University of Utah Medical Center. The examiners were blinded as to case vs. control slides.

Data analysis. A crude measurement of exposure to the sun was derived by the use of the formula: Sun Exposure = (0.6 × % of work time outdoors + 0.4 × % of off-duty time outdoors) × age.

Occupational histories were coded according to work in oil shale, other oil work, uranium mining, other mining, farming and ranching, and several other miscellaneous groups. The oil shale jobs were grouped into three categories: (1) production (mining retorting), (2) engineering and research, and (3) administrative.

Chi-square tests and *t* tests were used to compare responses and characteristics between groups, and a logistic regression model was used to relate oil shale work plus such confounding variables as sun exposure and smoking to the presence or absence of skin, urine, and lung abnormalities. The statistical power of the study was 90% to detect a doubling from a prevalence rate of 5–10% of skin tumors in the oil shale workers with a sample size of 325 persons and a significance level of .05 using a two-tailed test.

RESULTS

Demographics. There were 325 oil shale workers and 323 coal miners with a mean age of 56 yr for both groups. The oil shale workers had spent a mean of 6.0 yr in oil shale work; however, 50 % of the oil shale group had worked < 4 yr. The mean years for oil shale production work was 2.9 yr with 90% having worked < 8.4 yr. The oil shale workers had a mean of 1.3 yr in other oil work, 1.9 yr in uranium mining, 2.0 yr in other mining, and 3.4 yr in farming. The oil shale group had 28% current smokers with a mean of 35 pack-years versus 37% for the coal miners with a mean of 25 pack-years.

Respiratory symptoms. Table 1 illustrates that the prevalence of respiratory symptoms was similar to or less than that of the coal miners in all categories. The respiratory symptoms did not significantly increase with increasing years in oil shale work among the smoking or nonsmoking groups.

Skin examinations. Sixteen men in each of the groups were suspected of having 1 or more tumors. Each of the suspected tumors was biopsied; 8 basal cell

carcinomas were identified in the coal miner group, while 2 basal and 2 squamous cell carcinomas were found in the oil shale group. The latter 4 tumors were on the nose, face, neck, and finger, respectively. The corresponding exposures for these four men were: 2 yr as office manager in oil shale for the first; 2 yr in oil shale as miner and foreman, but 19 yr in uranium mining for the second; 3 yr in oil shale as powderman and carpenter, but 9 yr in processing uranium and vanadium plus 38 yr in ranching for the third; and 4 yr in oil shale in mechanical design for the fourth. In addition, 21% of the oil shale workers vs. 11% of the comparison population reported having skin tumors removed in the past. Among the oil shale workers, close to 150 surgical removals of tumors, moles, cysts, and other abnormalities were noted. Of these, about 65% were skin tumors, 25% were moles and cysts, and 10% were other tumors. Of the reported skin tumors, 60% were said to have been on the face, head, and neck; 15% on the arms, wrists, and hands; and 5% on the legs and feet. Many people reported multiple cases of skin tumor removal.

Five of the coal miners' group had 7 possible pitch warts among them while one of the oil shale workers had a total of 6. That individual had spent nearly 10 yr in oil shale production. Table 2 lists the number of actinic keratoses per person. Six percent more of the oil shale group had actinic keratoses, and the average number per person, given that they had at least 1, was greater than the comparison group. There were no differences between the two groups for nevi, pigment changes, telangiectasiae, and papillomata (Table 3).

A logistic regression model showed a significantly increased prevalence of actinic keratoses associated with oil shale exposure ($P < .01$). 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.

Cytology examinations. Sputum cytologies were obtained on 289 oil shale workers and 289 controls with 1 case of neoplasia detected in the control group. There was a significant association ($P < .05$) with metaplasia and oil shale production work among both smokers and exsmokers.

Urine cytologies that were free of inflammation and infection were evaluated on 277 oil shale workers and 295 controls. There were 58 oil shale workers with moderately or markedly atypical findings versus 31 controls ($P < .001$); 218 oil shale workers had negatively or mildly atypical findings versus 263 controls. When the data were broken down by smoking habits, nonsmokers had almost equal prevalences, smoking oil shale workers had a slight excess, and exsmokers had a three-fold excess. Analyzing for the effect of oil shale production exposure and allowing for age and pack-years showed no association of presence of abnormal cytology with any of these factors.

DISCUSSION

Several health parameters of 325 oil shale workers employed during 1948–1969 at the Anvil Points demonstration oil shale facility were studied. We felt it important to investigate their current health status because of the interest in developing a commercial oil shale industry as part of a larger synthetic fuels and alternate energy industries in the United States. The workers were traced and studied during 1978–1979 allowing for a 10 to 30 yr latency period for any adverse health effects to become manifest. However, the group was a survivor group and may have been healthier or less exposed than the entire oil shale workers cohort. Also, we only studied two-thirds of all survivors since

Table 1.—Symptoms for each Study Group by Smoking Habits

	Number		Prevalences (%)									
			Morning Cough		Morning Phlegm		All Day Phlegm		Wheeze		Breathlessness	
	OS*	C†	OS	C	OS	C	OS	C	OS	C	OS	C
Smokers	91	118	66	64	60	60	42	44	32	47	9	34
Exsmokers	162	125	28	50	28	54	31	50	26	55	14	50
Nonsmokers	72	80	18	44	21	45	18	43	11	46	3	38

* OS = oil shale.
† C = controls (coal miners).

Table 2.—Distribution of Men by Number of Keratoses per Person

	Number of Keratoses Per Person							
	0	1–4	5–9	10–19	20–49	50+	Not Noted	Total
Oil shale	184	89	24	16	9	2	1	325
Controls	205	83	15	14	6	–	–	323

Table 3.—Dermatological Examination Findings

	Mean Number Per Person		Percentage With 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

several were untraceable, and many were at scattered, isolated places throughout the United States. Our examination teams traveled extensively in Arizona, Wyoming, Colorado, California, New Mexico, Texas, Oklahoma, Nevada, and Utah to locate and evaluate the workers as best as possible. The workers also had rather limited and short exposures because of the nature of the oil shale demonstration plant. This was a major limitation of the study since few workers that we were able to trace were actually production workers (only 10% of the oil shale production employees worked $\geq$ 8.4 yr and 50% of the whole group worked $<$ 4 yr). Lastly, the choice of a comparison group that would be similar in age (a rather old mean age of 56 yr for a working population) proved difficult because most industries in the Colorado plateau region are of a resource extraction nature that involve exposures to carcinogens, skin irritants, or fibrogenic and irritating dusts. We considered uranium-vanadium miners, smelter workers, hard rock miners, and trona miners, rejecting all for the aforementioned reasons. Coal miners were chosen because this was an older working population located in one area, had been very cooperative in previous studies, and were disparate in their exposures, although we realized that their complaints of respiratory symptomatology would be high.

Despite these shortcomings, several interesting associations were found. Actinic keratoses were associated with oil shale exposure after controlling for age and sun exposure. Four skin cancers were found and although their relationship to oil shale work was tenuous, the oil shale workers reported more skin tumors being removed in the past than the controls. Metaplasia on sputum cytology examination was associated with oil shale production work among those who also had a history of smoking. Oil shale workers also had significantly more moderately and markedly atypical findings on urine cytology, although oil shale production work was not significantly associated with atypical urine cytologies using a logistic regression model. However, exposure to radon daughters in uranium mining and milling was a potential confounding variable. Respiratory symptomatology, at least among the smokers, was as high as in long-term coal miners.

Skin cancer and shale oil dermatitis was reported by Alexander Scott who studied Scottish shale oil workers in the early part of this century working under poor hygienic conditions.[2] He reported 65 cases of epithelioma from 1900 to 1921 among approximately 5,000 Scottish shale oil workers. Most occurred on the scrotum, while the remainder occurred on the arms, hands, or face. We did not find any cases of scrotal cancer in our study. S. A. Henry has chronicled the experience of scrotal cancers occurring in the English cotton textile industry where spindles were formerly lubricated with shale oil (mule spinner's cancer).[3] As early as 1922, Scottish shale oil was shown to produce skin papillomas in animals by skin painting experiments.[8] Scott also reported on oil shale dermatitis finding comedones, folliculitis, erythema, papular eruptions, and pustules to be common.[9]

In Estonia, Purde and Rahu did a retrospective cohort study of 2,069 oil shale workers exposed from 10 to 20 yr and found an excess of skin cancer among female employees.[10] Increased incidence was associated with a record of longer service in the oil shale processing industry. A further study corroborated these early results, and found a shorter dose-induction period in oil shale workers than controls.[11] Loogna and Hering reported dermatitis, eczema, folliculitis, and verrucea in Estonian oil shale workers.[12]

During 1952 to 1954, the U.S. Public Health Service examined 266 workers for skin abnormalities at the Anvil Points facility.[13] The percentage of workers having skin lesions and severe, light, or no contact with shale oil was virtually identical. He was unable to assess the distinct effects and interactions among age, sunlight exposure, and oil shale work because of small numbers and the short duration from onset of exposure. This study was actually a forerunner to the present study.

Skin painting experiments on animals have been performed on Colorado shale oil with positive results.[6,14,15] J. M. Holland et al.[6] produced tumors with a mean latency of 154 days in 47% of 30 mice by skin painting with a 50% solution of Colorado shale oil for 22 wk followed by 22 wk without exposure. Coomes has presented data demonstrating that 39/40 mice painted twice a week with crude shale oil developed tumors, but only 5/37 treated in the same way with hydrotreated shale oil (upgraded, reducing the nitrogen content) developed tumors.[14] Rowland et al. used the skin-painting techniques to test raw oil shale, spent oil shale, and shale oil coke resulting in 0/50, 6/50, and 48/50 mice, respectively, with tumors.[15] Results of three studies of dermatotoxicity of Anvil Points oil shale performed during a pilot operation 1977–1978 were confirmatory, although the authors cautioned that shale oils from different oil shales processed at different temperatures or conditions might give slightly different results.[16–18]

The present study does not identify an increased rate of skin cancers in humans exposed to oil shale and shale oil emissions. Possible explanations for this unexpectedly negative finding were reviewed previously. We did, however, identify a correlation between shale oil exposure and the premalignant lesion of actinic keratosis. This suggests that shale oil exposure may have some additive effect with sunlight in producing potentially malignant cutaneous lesions. Such a hypothesis, however, would have to be evaluated by subsequent investigations.

Respiratory symptoms were common among smoking oil shale workers similar to coal miners but uncom-

mon (3–21%) among nonsmoking oil shale workers. The increased prevalence of respiratory symptoms among these long-term underground coal miners has been reported previously.[19] Chronic bronchitis was reported by Wright and Rom in 34.9% of 86 oil shale workers formerly employed at Anvil Points.[20] They suggested that smoking, older age, and other exposure factors, particularly in mining, crushing, and processing other ores, might account for this. They also found 6 oil shale workers with pneumoconiosis versus 2 in an internal comparison group, but 3 of the 6 had other mining experience and all were smokers. Chronic bronchitis has been reported to be 2.5X times more prevalent among Estonian oil shale workers than age-matched controls.[21] Acute respiratory conditions and pneumoconiosis have also been reported.[5,22,23] Seaton et al. recently reported 4 cases of complicated pneumoconiosis diagnosed towards the end of a lifetime's work in underground oil shale mines in Scotland.[4] They reported that the clinical and histological features resembled the pneumoconiosis of coal miners and kaolin workers and that the lungs of 3 patients were shown to contain dust composed predominantly of kaolinite, mica, and silica.

Although we did not have industrial hygiene information, the results of an industrial investigation at the Anvil Points facility during a 1977–1978 pilot run were reported recently.[24] Generally, area samples were taken because of personnel changes or frequent rotation of jobs because of the pilot nature of the operation. Elevated dust levels were identified in the mining, crushing, and retorting areas indicating the need for dust control strategies, although 8-hr time-weighted averages were not calculated. The quartz content of air samples ranged from 5 to 10%. Gas and vapor levels in mining, crushing, retorting, and spent shale handling did not exceed present standards, but the composition of airborne organic materials present in those areas remains to be defined or characterized.

In summary, we evaluated the dermatologic, respiratory, and urinary systems of 325 oil shale workers employed during 1948–1969 at the Anvil Points oil shale facility. There were four cases of skin cancers among the oil shale workers, and actinic keratoses were significantly related to oil shale work as well as sun exposure and age. Metaplasia on sputum cytology was increased among oil shale workers who smoked, with a similar increase in the urine cytology dysplasia among oil shale workers who smoked. Dust control measures, proper hygiene to minimize skin contact with oily residues and good washing facilities, and medical surveillance of these three organ systems, in particular, appear warranted.

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