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Introduction

One of the principal occupational health concerns in the U.S. oil shale industry is the potential for pulmonary damage after inhalation of either raw or spent shale dusts. Along with other biological tests, inhalation studies with materials from the new U.S. industry have just begun. Comparison with both experimental results and epidemiology findings of scientists in countries with established industries can be of benefit in predicting the hazards of large-scale shale oil extraction in the United States. Health effects studies associated with oil shale extraction in the U.S.S.R. have been well established for several decades and are a valuable source of information. Purro and Kuhn did not find an increased incidence of lung cancer among 2000 oil shale workers involved in a retrospective study.[1] Vosamäe performed intratracheal experiments in which she instilled various solid oil shale materials or their extracts into rats. There was no increase of pulmonary neoplasia attributed to any of the solids, however, when tars derived from the solids were instilled under conditions that favored penetration of tissues by carcinogens (i.e., in detergents), an increased lung tumor incidence was observed.[2] Pathological changes observed by Kung

in autopsy material from oil shale workers revealed mild coniotic fibrosis, some focal and diffuse emphysema and signs of chronic bronchitis.(3) Small groups of U.S. oil shale workers have been examined with inconclusive results and most pulmonary changes, observed clinically, had a strong correlation to smoking history.(4,5)

Inhalation and intratracheal experiments have been performed using Green River shales from the western United States. None of these studies have revealed a lung tumor incidence above background, but lung fibrosis has been observed.(6)

Current studies comparing the effects of long term inhalation of either Estonian kukersite or American Green River shales are reported here. Actual exposure to kukersite was initiated in the spring of 1960, and most of the animals are still alive. The results reported here represent interim findings.

Materials and Methods

The Green River shales were random samples taken from the storage piles at the Department of Energy (DOE) Anvil Points, Colorado site. These ores average about 25 gallons/ton and the quartz content averages about 10% (3-17%). Estonian kukersite was obtained from the Oak Ridge National Laboratory oil shale repository which is maintained under joint Department of Energy/Environmental Protection Agency sponsorship. The Estonian materials were supplied to the repository by Dr. Pavel Bogovski under the joint U.S./U.S.S.R. agreement dealing with oil

shale.(7) With our analytical methods, the kukersite assayed at almost 90 gallons/ton (Fischer assay equivalent) and was found to contain 5–6% quartz. The quartz used in control experiments was obtained from a commercial source (Pennsylvania Glass Sand Co., Pittsburg, Pa.) and is a graded product in which 95% of the particles have a [illegible] below 5 μm.

Sixty-two [illegible] Fisher-344 rats were used in each exposure group. Exposures were in the nose-only mode and were conducted for 6 hours/day, 5 days/week. Details of the chambers and exposure methods are included elsewhere in these proceedings. a/ The design of each experiment is illustrated in Table 1. In order to conserve material, the aerosol concentrations used for Kentucky oil shale and quartz were approximately one-third that of the Green River shale (3 mg/m³). Particle concentrations [illegible] were approximately equal to the levels of particles found in Green River studies (1).

Exposures have been terminated for several months of the life span of this strain of rat under our laboratory conditions. No planned sacrifices have been performed, however, additional groups of animals exposed to Green River shales have been used in unrelated sacrifice studies that are not reported here. The principal endpoints in the experiments are pathological changes in the upper respiratory system with particular emphasis on the respiratory tract. Animals in all experiments were weighed on a monthly basis to monitor growth, food consumption, and general health.

TABLE I

Material	Animals	Concentration	Frequency	†Elapsed Time
Estonian Kukersite	F-344 Rats	* 50 mg/m	6 hrs/day 4 days/wk	12 months
Green River Shale	F-344 Rats	**.150 mg/m	6 hrs/day 4 days/wk	20 months
Quartz	F-344 Rats	***.15 mg/m	6 hrs/day 4 days/wk	16 months
Sham Controls	F-344 Rats	----	----	20 months
Colony Controls	F-344 Rats	----	----	15 months

*38% respirable
**5% respirable
***80% respirable

†Elapsed time in experiment by June 1, 1981

Results and Discussion

No lung tumors attributable to inhalation of oil shale dusts have been observed in any exposed animals, however, none of the studies are complete. In the studies with Green River shales, which were the first to begin, the rate of deaths has increased as the animals approach two years of exposure. We have sacrificed two animals in the Estonian kukersite group in order to observe the status of the lungs at this point.

Fischer-344 rats exposed to American shales have shown varying degrees of lung fibrosis which is clearly related to length of exposure. Animals dying or sacrificed at an early time exhibited minor changes (i.e., slight thickening of interalveolar septa, slight increase in collagen, etc.). Animals dying in the later stages of the experiment (after [illegible] months) exhibited more pronounced changes [illegible] thickening of interalveolar septa and focal [illegible] (Fig. [illegible]). The two animals sacrificed in the kukersite exposure group exhibited only mild changes with some interalveolar thickening, increased numbers of macrophages and some increase in collagen. Identification was made by using Masson's trichrome method (Fig. [illegible]). Quartz exposed animals [illegible] after several months exposure and animals dying after [illegible] months often exhibited [illegible] and pneumonia (Fig. [illegible]).

In previous experiments with Green River shale [illegible] Syrian hamsters were exposed either by inhalation or intratracheal instillation, varying degrees of fibrosis were observed but no lung tumors were identified. [illegible] In a recent

study, Kenne exposed Wistar rats to either silica or Green River shale and observed fibrosis and lipoproteinosis but no neoplastic changes.(9)

Early increases in collagen can be identified using classic staining and histochemical techniques and can serve to give an early indication of fibrosis. The question of whether fibrosis is progressive after a certain level of insult has not been adequately answered nor has it been determined if there is a point of reversibility in collagen formation. The principal observation from inhalation studies with U.S. shales has been a straightforward fibrogenic response similar to that seen following inhalation of many mineral dusts. We cannot make any judgements based on only two of the animals exposed to Estonian shale, however, we have identified small amounts of neocollagen in lung parenchyma associated with inhaled shale particles. Shale dust has been translocated to the regional lymph drainage with considerable accumulation in the hilar nodes of all animals observed so far. Neutron activation studies of rat tissues following various periods of exposure have shown that there are minor increases in certain shale-related elements in kidney and liver. These studies have also illustrated that the major translocations are to the lymphatics and the gastrointestinal tract.(10) The accumulations in the alimentary canal are transitory and reflect transport out of the lung followed by swallowing and elimination in the feces.

Anticipated worker exposures in a growing U.S. oil shale industry will not be simple, single factor phenomena. Some

workers will be exposed to a number of products such as raw shale dust, spent shale dust, and vapors and gases from retorts. Occupational histories in U.S. worker populations can be extremely complex and epidemiological findings will be hard to interpret. Information derived from the experience in the U.S.S.R. with an established oil shale industry will be very helpful. The low incidence of severe pulmonary disease in the Estonian industry is encouraging. There are [illegible] differences in the chemical make up of the [illegible] shales, however, the opportunity to compare [illegible] materials and [illegible] [illegible] of the [illegible] the [illegible].

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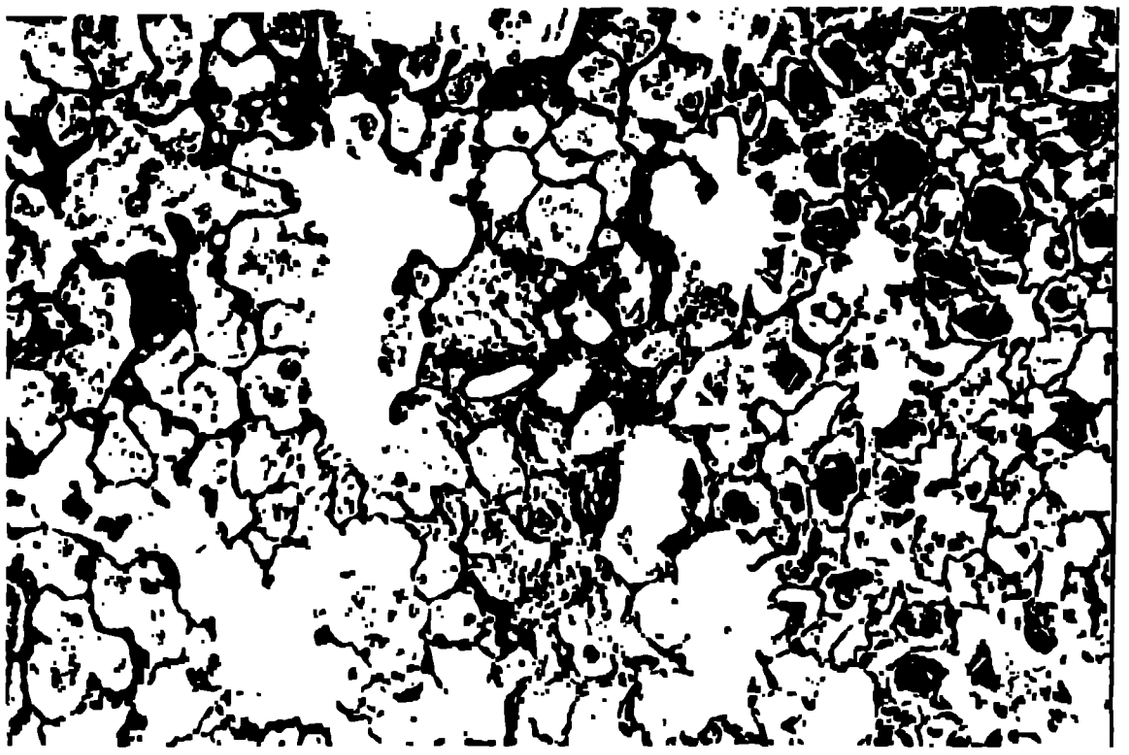

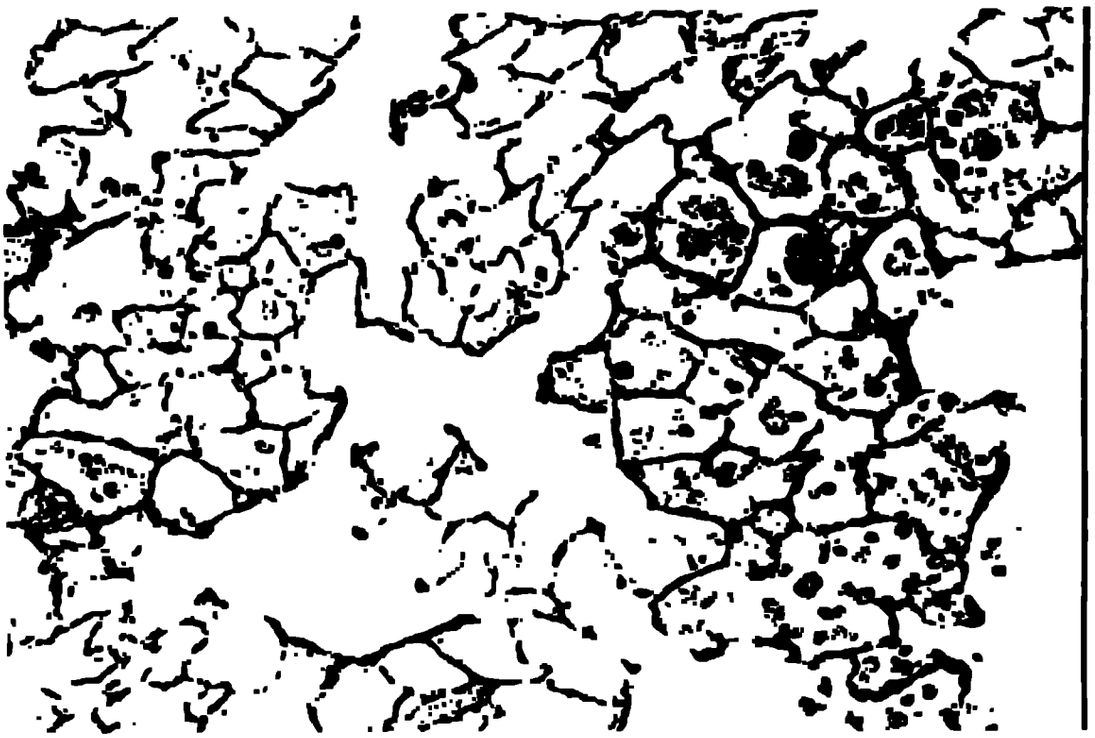

Fig. 2. Histological section of a rat lung exposed to Estonian oil shale dust. Many alveoli contain dust bearing macrophages. Masson's trichrome stain. Exposure period: 12 months at 50 mg/m^3.

FIG. 1 Histological section of a rat lung exposed to silica (quartz) dust. Focal scarring surrounds blood vessels and a bronchiole. Dark lines represent collagen. This section was taken 3 months after intratracheal exposure to 25 mg of silica. Masson's Trichrome stain.

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