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A Viewpoint on Occupational Health in the Oil-Shale Industry

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Studies of potential health effects from work in the oil shale industry are developing a body of information that will determine the extent of future health protection measures for the workers. The value of this work will depend on the interpretation and use of these data. The collection of this information comes at a early time in the development of the oil shale industry; it is also at a time of heightened interest in occupational health, safety, and environmental protection. Because of these factors it is useful to stand back and take a broader perspective of activities in this field. That is the objective of this paper.

First, it is probably important to recognize exactly where we are in the oil shale industry as well as in occupational health and safety programs. Oil shale, as you know, is not a new resource; it has been known and used since before Drake's discovery of oil underground in Pennsylvania in 1859. Despite this, the industry is still in its infancy. This fact is important for putting our viewpoint in proper perspective.

A second concept of importance is the responsibility placed on industry management today to provide safe work environments and facilities. The practice of occupational health, using disciplines such as occupational medicine, safety, and industrial hygiene, has been receiving increased attention through the years, particularly since World War II. The Federal legislation of extensive regulation in occupational health and safety in the United States has stimulated the need for active programs by all industry. This has led to concepts of protection which in some instances are expressed as requiring exposures to be "as low as reasonably achievable" or "as low as practicable." There is a search for almost absolute safety in the work place, an achievement we do not find even in our everyday personal lives at home or at play.

The practitioners of occupational health are beginning to find themselves in a new role. Historically, the professionals in medicine, safety, and industrial hygiene have addressed problems that have developed in operating industries. The activities of these preventive health disciplines have been employed in a reactive mode to assist in solving recognized problems. This experience has made it possible to improve the work environment and facilities. The lessons frequently have been used to prevent problems during the design of new procedures or facilities in an operating industry. The influence of occupational health activities on an embryonic industry is more difficult to predict. This is a relatively new ballgame.

Occupational health studies in the oil shale industry are beginning to develop a significant base of information. Most of it is a variety of research data collected at or on specific sites. The information must be interpreted and used in developing this new industry. Occupational health now finds itself in a new situation with a new challenge to take this basic knowledge and project it into safe procedures and facilities. Our experience in interpreting such data to predict health consequences is extremely limited. In an industry that has limited history, such as the oil shale industry, this projection of basic information into a practical industrial setting may be much more difficult than appears at first glance. The reason for presenting a different viewpoint is to attempt to analyze and project this new role played by occupational health and environmental science in this situation.

Data Interpretations

Information relevant to potential occupational health problems in oil shale is being collected from a number of sources, including air sampling and measurements in a few work areas, analytical characterization of pollution sources, dusts, gases, and vapors; a variety of cellular and animal toxicology studies; and others. Each of these provide values or results on a specific sample or situation. Each requires an interpretation. To project this information to the practical health protection of workers in a commercial industry requires the integration of a large quantity of information. The end result of this interpretation is what will be applied to health protection in future planning of procedures and facilities.

One concern is how well we will interpret this information and apply it. There are concerns that potential health problems may exist and not be recognized early. There is a significant effort to identify these problems. This work will result undoubtedly in recognizing occupational health risks. These will be looked at from an unusual vantage point for occupational health; namely, the perspective of looking forward at future potential problems rather than responding to known existing problems. It is important that we be sensitive to the lack of experience of interpreting data in this situation. It is the variability of interpretation and the important impacts of our responses to interpretation that make this philosophical argument significant.

One might compare the data generated on occupational health matters with the information content of a photograph. We have no difficulty recognizing all features of a photograph if presented as an image that is identical to the optical signals we use in real life every day. This is referred to as a "positive" film or print. In most photographs the information on the print comes from a negative, which contains the same information content as the positive. For most of us, looking at the negative is not nearly as meaningful as the normal image. The negative contains a strange set of signals to interpret. The content and fine features in the negative escape us rather easily. With intense study or experience we may translate most of the information into a reasonable interpretation. In general, however, we have difficulty in recognizing the picture in detail immediately from a negative. Yet all the information is there.

Occupational health research data interpretation may present somewhat similar problems of interpretation. The information is being projected in a new perspective. We are not experienced in looking at bits of information and projecting risk values into a large picture of a commercial industry. It is likely that we will be guilty of either missing, underestimating, or overestimating the significance of various bits of information. In today's setting of occupational health regulation it is possible, more likely probable, that the occupational health data interpretations will be used to estimate the minimal risks to workers that are deemed to be "practicable." This also is a judgment area in which we have had little experience in an industry that is yet to be developed. This concern for interpretation and application of occupational health data is probably more appropriate when we evaluate individual bits of information and apply them to future industrial worker environments. It suggests that we should be particularly careful to not overinterpret individual pieces of information.

Is there another means of obtaining an occupational health perspective in this industry? We think there is a viewpoint on occupational health that can project the big picture and with good perspective. The method is to apply broad viewpoints from similar experience in other industries that we understand in considerable detail. In other words, we can apply empirical experience gained by many years of occupational health protection of workers in industries that are judged to be comparable to the various work components in oil shale. It is this viewpoint of a current evaluation of occupational health considerations in the development of an oil shale industry that we wish to discuss.

Industrial Hygiene Perspectives and Comparisons

In assessing the potential health and safety hazards which may be expected in a large-scale oil shale industry, it is useful first to examine the types of operations that will be utilized to extract oil from oil shale. These may be broadly characterized as 1) mining, 2) raw shale processing and handling, 3) retorting and refining, and 4) spent shale disposal. With few exceptions, these operations in shale oil production are similar to operations in existing industries. Health and safety risks and occupational health controls would also be expected to be similar.

1. Mining

Both underground and surface (open pit) mining of oil shale are expected to be very similar to other types of hard-rock mining in which drilling, blasting and ore handling occur. Potential health hazards include exposure to dusts during most activities, and exposure to gases or vapors produced by blasting and use of diesel vehicles. With the exception of modified *in situ* (MIS) retorting, as will be discussed below, the potential hazards appear to be similar to those in other types of hard-rock mining. An important health hazard in oil shale mining appears to be exposure to free silica-bearing dusts, and controls will be necessary to ensure that miners are not exposed to unacceptable levels of such dusts. Although oil shale in the Green River formation is reported to have a quartz content of 10 to 20%, measurements in the mines at Anvil Points and the C-a tract in Colorado have shown results in the 3 to 10% range. Some reduction in percentage is attributed to dilution of mine dust by diesel exhaust products. To date, neither the industrial hygiene or toxicological studies have demonstrated that any unique hazards are associated with raw oil shale dusts.

Exposure of miners to excessive levels of noise is another potential health hazard that will require control in oil shale mining. This hazard is not unique to oil shale mining. As with other types of mining, high noise levels are associated with mining machines, drills, booster fans, and other equipment. The controls will be similar to those in other mining operations.

The MIS oil shale retorting process may present some unique occupational exposure problems. Commercial-scale operation of MIS facilities will require large-scale underground mining activity in preparation of retorts at the same time that previously-prepared retorts are burning or have been abandoned. This situation offers some possibility of exposure of underground miners to fugitive emissions from burning or abandoned retorts in conjunction with the airborne materials normally produced in underground mining. Air sampling for a number of gases and vapors during the burn of a demonstration-scale MIS retort has not indicated levels of any air contaminants that would be of concern. Results of that study are summarized in the final paper. Additional study of this potential problem will be required as additional commercial-scale MIS retorts are developed. Existing data are limited to operation of one MIS retort at a time and do not include atypical situations.

The preparation required for true in situ oil shale retorting is done with aboveground drilling, similar to that required for oil and gas extraction. Health and safety hazards associated with such drilling would be expected to be similar to those encountered in drilling for oil and gas, except that hazards by gases such as hydrogen sulfide will not likely be present due to the shallow drilling depths. No unusual problems are anticipated here.

2. Oil Shale Processing and Handling

The processes involved in oil shale processing and handling, i.e., transporting, crushing, size-classification, etc. are similar to those utilized in most types of mineral processing operations. Health hazards will consist primarily of exposures to silica-bearing dusts and noise. Control techniques for dust control in mineral processing operations are well developed.

3. Oil Shale Retorting and Refining

With the exception of the in situ techniques, the processes involved in the retorting of oil shale materials are generally similar to processes presently utilized in mineral processing (such as the calcining or roasting of ores) and in conventional petroleum processing. Retort offgases contain a large number of gases and vapors, including high concentrations of carbon monoxide, hydrogen sulfide, ammonia, and an extremely complex variety of organic vapors. As in the petroleum industry, these offgases will normally be contained within gas-tight piping and vessels. Fugitive emissions will require careful attention in the design and construction of appropriate control equipment, as well as a program of maintenance to minimize leaks. This is not, however, a new problem and experience in controlling such vapor streams is well advanced.

As indicated above for MIS retorting, fugitive emissions also represent a concern for true in situ retorting of oil shale. The cracking of the ground surface above the retorts during blasting allows retort gases and vapors to escape during the burn of the retorts. However, recent air sampling during the burn of a commercial-scale in situ retort indicates that such retorts can be operated in a manner which results in no recognizable hazards to worker health under normal conditions. Sealing techniques are also being developed to reduce leakage from the ground surface above such true in situ retorts.

Maintenance activities at oil shale facilities as in the petroleum and petrochemical plants, represent a special situation in which workers may be exposed to high levels of gases, vapors, mists, and dusts after opening up sealed sections of the system or working in close proximity to leaking valves or seals. Due to the carcinogenic nature of shale oil, personal protective equipment and washing facilities must be provided to minimize exposures to the skin and respiratory system. The higher boiling fractions of petroleum oils have also been demonstrated to be carcinogenic in animal tests. The petroleum industry has implemented programs to minimize worker contact with oils, gases, and vapors. Protection of workers in oil shale facilities should be comparable.

It is expected that shale oil refining will pose no unique hazards to workers. Most shale oil will be refined in conjunction with conventional petroleum crudes at existing refineries. With the exception of a higher nitrogen content, which may result in the formation of compounds, such as aromatic amines, shale oil does not appear to possess properties which are not already encountered in the range of conventional crude oils. The presence of some trace elements, such as arsenic, may require that shale oils be treated prior to being refined. Neither these potentially toxic or elements or the treating processes, however, are expected to result in potential worker hazards to an extent as great as in some other mineral and chemical processes.

4. Spent Shale Disposal

As with the mining and processing of raw shale, the primary concern from the perspective of worker health and safety with the disposal of spent shale appears to be due to silica-bearing dusts. The dusts also contain some retorted organic matter which may contain compounds which are potentially carcinogenic. Disposal of spent shale is in many ways analogous to disposal of ash remaining from the combustion of coal, but the size of particles in spent shale is expected to be much larger. Dust control measures, such as wetting of the spent shale, should effectively control these problems.

Safety Perspectives and Comparisons

Safety hazards in oil shale should be similar to those encountered in industry, such as, materials handling, and ore crushing. Accidents result from rock falls, explosions, bumps, falls, and other physical injuries including those from electrical systems, moving vehicles, and other mining equipment. A unique feature of projected commercial-scale shale oil production is the extremely large volumes of shale to be mined. It appears unlikely that this magnitude of the operation should effect safety risks appreciably assuming that conventional safety techniques are applied conscientiously.

It is worth noting the safety record of the mining industry for 1977-1979, according to the National Safety Council. The incidence rates per 100 full-time employees (200,000 employee hours) for OSHA recordable occupational injury and illness is 10.0 compared to 8.2 for all industries. Within the mining industry the recordable cases for mining involving coal, oil, and gas is about a factor of 2 lower than mining for metal and nonmetallic minerals, except fuels. The recorded cases involving days away from work and deaths is the same for mining as for all industries, namely, 2.6 cases per 100 full-time employees. The experience for the mining in general suggests that protection for oil shale workers should be reasonable. To date, the accident rate for oil shale mining has been considerably better than that for all mining combined.

Deep underground oil shale mines appear to be similar to coal mines in that the mines are "gassy," which will require that such mines be well ventilated to prevent methane concentrations from reaching explosive levels. Finely divided oil shale dust is reported by the Russians to be flammable and explosive. Fires in spent shale piles have occurred and are similar to those experienced in coal seams or piles. These hazards have been reasonably controlled in other industrial processes.

Occupational Medicine Perspectives and Comparisons

Medical studies on workers in the oil shale industry who have been exposed to shale dusts and oil products have alerted us to several potential problem areas. Chief among these are pneumoconiosis and skin cancers.

1. Pneumoconiosis

The presence of free silica in oil shale dust suggests the potential for fibrogenic lung disease. Its presence in oil shale miners has been noted infrequently. The Russian medical literature on the Esthonian oil shale workers covers a period of over 30 years of shale oil mining. Pneumoconiosis has not been noted by chest roentgenograms on these workers. Autopsy studies of Esthonian miners with 15 years or more of shale oil dust exposure show them to have moderate fibrogenic changes in the lung and in bronchopulmonary lymph nodes. A high incidence of bronchitis has been described in these workers. Nasopharyngeal changes of hypertrophic and atrophic rhinitis was also described.

The Scottish oil shale industry operated for over 100 years. Medical examinations were not performed on the miners. However, there does not seem to be any awareness of an unusual amount of lung disease by the workers or physicians in the region nor has there developed a folklore on illnesses in the oil shale workers. A. Seaton et al. described four Scottish oil shale workers who developed pneumoconoisis after very long work histories in shale miners. The work histories were 32, 47, 49, and 53 years of underground work. Two of these individuals were living at ages 60 and 83 years of age while two died at ages 76 and 82 years of age. The two latter cases had post-mortem examinations that revealed invasive squamous carcinoma of the lung without distant matastasis. This experience suggests that while pneumoconiosos is a potential disease after long periods of dust exposure, the disease is not as prevalent as the incidence of disease in hard-rock miners with comparable dust exposure. This would be expected on the basis of the free silica content in these various dusts.

Occupation medical surveys of oil shale workers in the United States have been very limited. The duration of exposures of these small populations have been relatively short, usually less than five years. A number of oil shale workers have had equal or longer history of work in hard rock mines and the occupational histories are often complex. No definitive correlation has been found with shale dust exposure thus far.

The conclusion, as in the industrial hygiene section above, suggests that control of dusts in this industry should be amenable to conventional methods of dust suppression. To date the potential for development of pneumoconiosis in oil shale mining, even without adequate dust suppression, appears to be relatively mild and infrequent compared to other mining situations.

2. Skin Cancer

The potential for shale oil to produce skin cancers is well documented in both animals and man. In Scotland the major medical problem associated with the industry was dermatitis resulting from intimate contact with crude shale oil and its derivatives. Another serious hazard was the development of skin epitheliomas. These cancers in the Scotts occurred in a relatively small group of workers who did the scraping of paraffin from the filter process. From 1900 to the 1960s about 100 cases of skin cancer were reported. The principal exposure involved extreme contact with the paraffins contaminated with crude shale oil. A relatively simple program of protection by use of newly designed vertical filter presses, gloves, rubber aprons, and better personal hygiene greatly reduced the problem after the 1930s. The shale oil product was used for lubrication of the weaving machinery in the cotton textile industry. A serious problem of skin cancer, especially scrotal carcinomas, developed in the cotton mule spinners. This was due to skin contamination with the oil product. These scrotal cancers resulted in over 500 deaths.

In the United States, the Public Health Service conducted a special study on potential skin problems in the early 1950s by means of dermatologic examinations of 266 workers at the Oil Shale Demonstration Plant at Rifle, Colorado. No relationship between the development of skin lesions and the degree of exposure was found. Other limited clinical surveys of workers at the Paraho Plant in 1978 and Geokinetics work force in 1981 have not shown any skin lesions related to work in the oil shale industry.

Studies on the Esthonian workers have shown a statistically significant increase of skin cancers. There seems to be a dose-effect relationship between the length of exposure and skin cancer.

Skin cancers in workers have thus occurred in instances where there has been a high degree of contact with shale oil or special fractions of oil. It would appear the control by preventing contact and employing good personal hygiene will be adequate to prevent this problem.

Other Cancers

The potential presence of carcinogens in oils and vapors makes the incidence of cancer a particularly important subject. Unfortunately, present information in man is very limited. The medical literature on the Esthonian work force shows no increased cancers in organs such as lung and the nasopharynx. If increases have occurred they have not been recognized by conventional clinical studies.

Further information on this subject must await longer term epidemiologic study. A retrospective study of Scottish oil shale workers is thought to be feasible and is being proposed by the Institute of Occupational Medicine in Edinborough over the next three years.

It is worth noting that many occupational health programs deal with potential carcinogenic materials. It does not appear, by comparison, that the oil shale industry will be unique in this regard.

Epidemiology

Some of the questions raised by the above discussions might be answered better with formal epidemiologic studies. At the present time there are very limited populations suitable for study. The above mentioned Scottish proposal appears to be one of these. In the United States, the present oil shale worker population is too small for meaningful studies. It is apparent that information from such studies will not be available to guide the worker health protection programs in this developing industry. The answers from such studies will come much later. Therefore, the necessary information to guide development of worker protection in the earlier stages of development must come from other research information, such as toxicology studies and analogy of health experience from related industry.

Summary

A broad viewpoint of the prospective occupational health problems in the oil shale industry can be obtained by reviewing similar activities and exposures in other industrial operations. This approach has the advantage of providing long term, empirical information on humans who have worked with materials and exposures that are as hazardous or more hazardous than is anticipated in the oil shale industry. This viewpoint would suggest that the prospective problems can be controlled adequately by conventional methods of worker protection.

Several unique situations do exist in this industry. The mining and material handling of tonnages of oil shale exceeds any experience in other mining activities. This is a problem of scale. It seems unlikely that it will produce new safety problems.

The *in situ* mining offers the unique situation of burning and abandoned underground retorts in near proximity to work forces preparing future *in situ* retorts. The potential of exposures to dusts, gases and vapors will simply have to be measured as such operations come on stream. Measurements made to date have not shown unique hazards to exist, although existing data are limited to demonstration-scale retorts burning one-at-a-time under normal conditions.

A unique study potential exists in this young industry for development of data bases for future epidemiologic studies. The vital information to be obtained includes complete personnel rosters, job descriptions, exposure indices, and means for long term follow-up, especially of persons who have retired or left the industry. Of these necessary ingredients, the development of useful exposure indices appears to be the most difficult to obtain.

There is expressed here some concern regarding interpretation of isolated bits of information relevant to occupational health in a prospective industry such as oil shale. This results partly from the current national objective to require programs that assure maximum worker protection. There is a danger of overinterpreting risks in this environment. A broad viewpoint based on experience from relevant industries suggests that worker protection programs in the oil shale industry will not require significantly new and different approaches to provide adequate and reasonable worker protection.