United States
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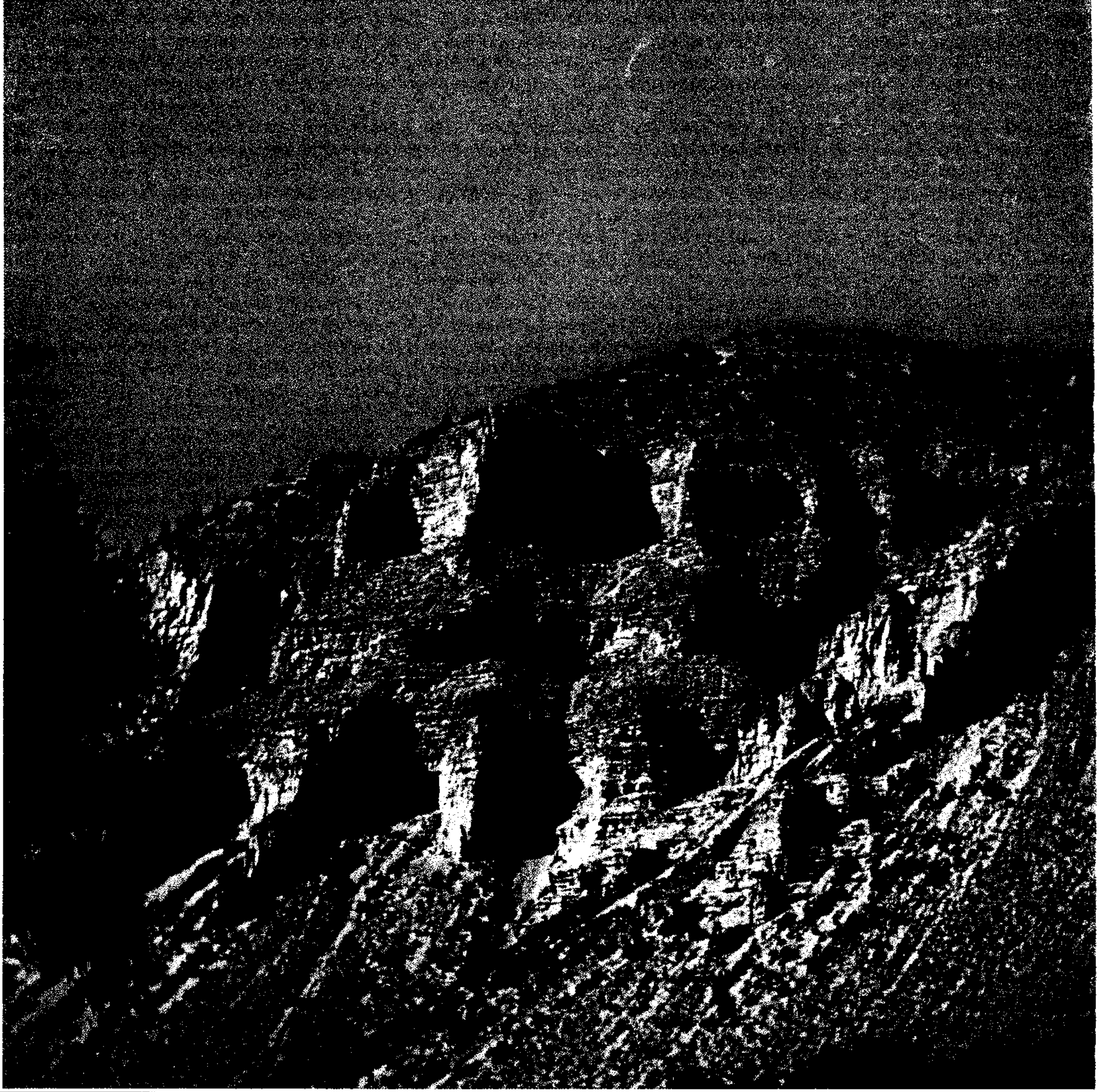
Industrial Environmental Research
Laboratory
Cincinnati OH 45268

Technology Transfer

EPA

Environmental Assessment

Perspective on the Emerging Oil Shale Industry



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Environmental Assessment

Perspective on the Emerging Oil Shale Industry

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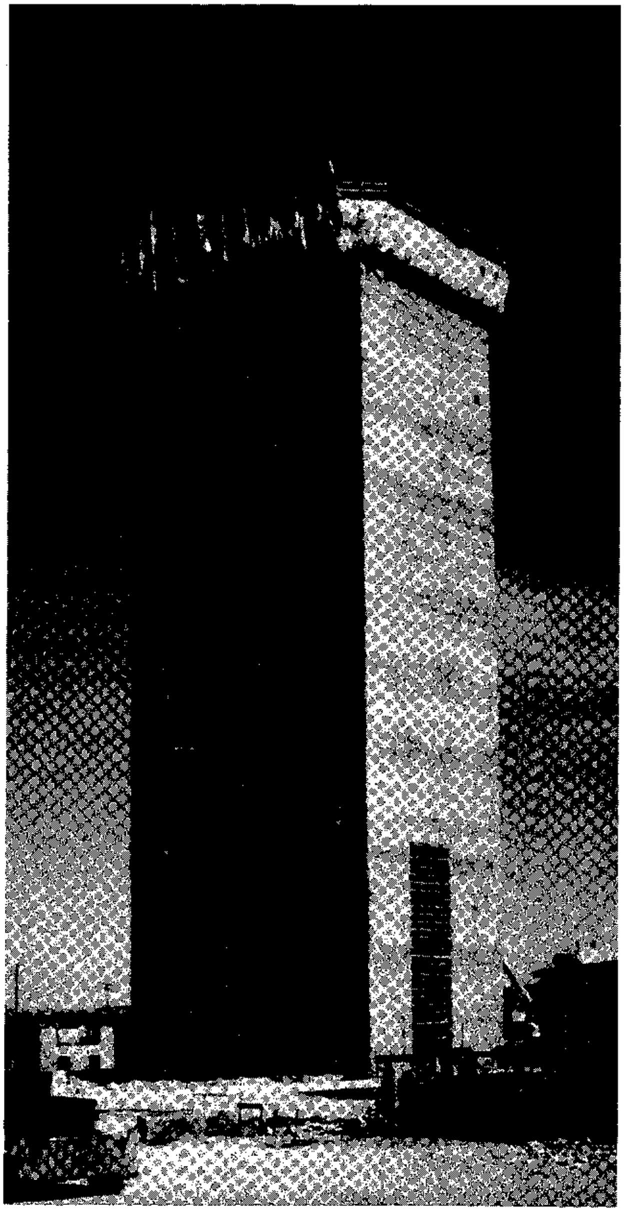

Construction of mining facilities for commercial oil shale development, Federal Lease Tract Cb in Colorado

When energy and material resources are extracted, processed, converted, and used, the effects of related pollution on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory in Cincinnati is engaged in developing and demonstrating new and improved methods that will meet these needs efficiently and economically.

This report provides a brief summary of a more comprehensive report, *Environmental Perspective on the Emerging Oil Shale Industry* (EPA 600/2-80-205). The full report provides a preliminary overview of environmental considerations related to the emerging oil shale industry. The report and similar ensuing reports are intended to develop the technical basis for eventual regulations.

The recently announced national synfuels program relies on development of the oil shale industry. We believe providing information on environmental concerns and developing control technology in concert with development of oil shale technology will enable the establishment of a mature oil shale industry compatible with national environmental goals without unnecessary delay.

Further information on the subjects of this report can be obtained from the Energy Pollution Control Division, Industrial Environmental Research Laboratory, Cincinnati, Ohio 45268.

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Introduction

Oil shale deposits in the United States are among the richest and most extensive in the world. (Principal deposits are shown in Figure 1.) Total identified resources of medium and rich shales in the Nation are estimated at 2 trillion equivalent barrels (320 billion equivalent cubic meters) of oil. The Green River formation alone—which covers an area of 17,000 square miles (44,000 square kilometers) in Colorado, Utah, and Wyoming—contains an estimated 1.8 trillion equivalent barrels (280 billion equivalent cubic meters) of oil. About 600 million barrels (95 billion cubic meters) is considered recoverable by currently known technology.

This environmental assessment report conveys the U.S. Environmental Protection Agency's (EPA's) understanding of and perspective on oil shale development. For government agencies, private developers, and others involved in the oil shale industry, the report provides a source of basic information as well as a means of identifying EPA's concerns and interests relative to oil shale development. The report:

- Summarizes available information on oil shale resources
- Summarizes major air, water, solid waste, health, and other environmental impacts
- Analyzes applicable pollution control technology
- Provides guidance for sampling, analyzing, and monitoring emissions, effluents, and solid wastes from oil shale processes

The report emphasizes those environmental impacts and control technologies that EPA believes will be of major importance.

Section 7 in the more comprehensive report, *Environmental Perspective on the Emerging Oil Shale Industry* (EPA 600/2-80-205a), and the companion appendix volume (EPA 600/2-80-205b) contain materials not included in this environmental assessment. Section 7 provides a technical review of major retorting methods and their probable emissions,

The Piceance Basin in Colorado, with recoverable oil shale resources estimated at 500 billion equivalent barrels of oil

effluents, and solid wastes. The appendixes comprise technical and data reviews:

- Appendix A. Status and Development Plan of the Oil Shale Industry
- Appendix B. Procedures for Ambient Air Monitoring
- Appendix C. Environmental Monitoring Activities—Past, Present, and Proposed
- Appendix D. Applicable Federal, State, and Local Legislation, Standards, and Regulations
- Appendix E. Quality Assurance Bibliography
- Appendix F. Federal and State Permits Required for Operation of an Oil Shale Facility

Recommendations and Conclusions

Shale oil production will combine a number of processing operations on one site: mining, ore preparation, retorting, gas treatment, refining, and solid waste management. The scale of operation will be massive. Consequently, the rates at which point source and fugitive pollutants are generated will require strict control. Potentially applicable control technologies employed in related industries—such as petroleum production, stone crushing, cement manufacture, and electric power generation—may not be directly transferable to shale oil production because of process mixes and integration.

The environmentally problematic effluents and wastes from oil shale operations have not been thoroughly characterized. In some cases, adequate sampling and analysis methods have not been developed, validated, and standardized. In a commercial operation the byproducts of retorting will usually be processed in some further way before their characteristics as potential pollutants can be identified and control technology developed. Site- and process-dependent pollutants, particularly trace organics and inorganics, may have the greatest potential impact on health and welfare. Finally, refining shale oil into end use products may result in increased emissions of toxic compounds.

Control technologies for treatment of off-gases are generally believed to be adequate, but they need to be demonstrated for key pollutants in off-gas streams. Additional studies are needed, however, to characterize off-gases from both in situ and surface retorting processes because of the potential for release of toxic trace elements.

It will be especially important to control particulates from mining and handling operations by use of suppression systems. Water sprays, along with wetting agents and organic binders, need to be evaluated for use at the points of emission as well as on haulways and ore piles. In-mine localized particulate removal by modular wet scrubbers, electrostatic precipitators, or baghouses needs to be evaluated. For example, whether electrostatic precipitators can be used to control particulates from mining and crushing operations will depend on characteristics of the dust. Raw oil shale dust resistivity has not been adequately investigated. Additional studies are needed, especially with respect to fine particulate control.

Because of the absence of a full-scale oil shale industry, the adequacy of control technologies for handling oil shale wastewaters is still questionable. Some oil shale developers contemplate using retort water to moisten retorted shale for dust control and to aid compaction. If the retort wastewater is used in this manner, the hazardous and toxic constituents might migrate to local surface and ground water supplies.

Modified in situ oil shale processing will generate more wastewater than can be consumed by process reuse. Subsurface injection or surface discharge may be necessary. Wastewater constituents may include hazardous organics (polycyclic materials, phenolics, amines) and inorganics (arsenic, molybdenum, vanadium, boron, among others). Control techniques must be developed, therefore, to ensure effective removal of these constituents before wastewater disposal.

Little is known about the movement of ground water into and through abandoned chambers of modified in situ operations. To date, only speculations have been made about the leaching of such chambers by ground water. Consequently, laboratory studies should be conducted to determine probable leaching rates and concentrations of organic and inorganic constituents. These studies should be supplemented by field monitoring of existing and near-future in situ retorting operations.

The disposal of solid wastes resulting from oil shale mining and processing is a major environmental concern. Retorted shale could present problems of surface and ground water degradation if pile stability and impermeability are not maintained. All research and monitoring programs to date have dealt with relatively small quantities of retorted shale. Potential problems, such as mass stabilization of shale piles and maintenance of an impervious layer below plant root zones, can likely be identified and solutions found only by creation of a large pile from commercial-scale processing.

- Providing adequate water quantities
- Maintaining air quality so as to protect health and welfare
- Minimizing detrimental land disturbances to preserve adequate habitat for wildlife
- Protecting valuable socioeconomic, cultural, historical, and aesthetic values

Source standards and ambient standards will apply to individual oil shale facilities and to an oil shale industry. The ambient standards most directly affect the industry as a whole, rather than any individual facility, in that the Piceance and Uinta Basins (and the Colorado River Basin) have a finite carrying capacity for air and water pollutants. Although attempts have been made to determine how large an oil shale industry could be without exceeding this carrying capacity, success has been limited because data are scarce and comprehensive predictive efforts rare. Obviously, facility siting is a major factor in making this determination.

In evaluating any permit application for a prospective oil shale developer, the logic is and will be as follows: First, the proposed pollution control equipment must represent best control technology as defined by EPA. Second, controlled residuals must not violate ambient standards.

The concept of Best Available Control Technology (BACT) for air emissions control has been defined as the maximum degree of reduction determined case by case, taking into account energy, environmental, and economic impacts and other costs. Standards of Performance for water effluent control must reflect the greatest degree of effluent reduction achievable through application of the Best Available Demonstrated Control Technology, Best Available Technology Economically Achievable (BATEA, or simply BAT) processes, operating methods, or other alternative; a standard permitting no discharge of pollutants should be included wherever practicable. In establishing performance standards EPA shall consider the cost of achieving the effluent reduction, any non-water-quality environmental impact, and energy requirements. Although disposal standard practices have not yet been defined for oil shale solid waste disposal, it appears that the concept of Best Engineering Judgment (BEJ) will be used. Factors associated with BACT and BAT will presumably help define BEJ.

Because industrywide performance standards do not exist for oil shale, all permit applications are evaluated case by case in terms of BACT and BAT. After applying BACT and BAT criteria, the permit writer assesses the impact of residuals on ambient air and water. If applicable Prevention of Significant Deterioration (PSD) increments or stream standards are predicted to be violated, better control than that prescribed by BACT or BAT must be employed. More stringent controls may be accomplished by reevaluating the economic and energy costs associated with BACT or BAT. Because it appears that PSD Class I air quality increments may limit the ultimate size of the industry, EPA Region VIII has encouraged potential oil shale developers to provide controls better than BACT to maximize oil production from the area.

In the June 7 and June 14, 1979, issues of the *Federal Register,* Parts 121-125 of 40 CFR provide guidance on strategy and procedures for National Pollutant Discharge Elimination System (NPDES) permitting. These regulations include critical definitions of terms such as "navigable waters." (In essence, navigable waters are any flowing waters, wetlands, or impoundments.) Moreover, the NPDES permit for a new source is now required before the source is constructed. Finally, if an Environmental Impact Statement (EIS) is necessary, a final NPDES permit may not be issued until a final EIS has been issued. In the past, EPA has encouraged oil shale developers to apply for NPDES permits even if they expect no discharge. The developer is then in a more advantageous position in case of future enforcement actions.

The refining of crude shale oil will produce a number of potentially adverse environmental effects, primarily as a result of atmospheric emission. Data have not been developed on the quality and quantity of these emissions. Such data may indicate a need for further study and for development of new control technology.

Water Quality

Water is necessary to the development of an oil shale industry. Water will be needed for dust control during mining and crushing, for gas cleaning and air pollution control, for cooling, and for moisturizing retorted shale. Upgrading crude shale oil, on-site power generation, and revegetating disturbed land and retorted shale disposal areas will also consume large quantities of raw water. The water needs per unit of net product will necessarily depend on the mining, retorting, and upgrading methods used. In general, in situ methods are expected to consume less water than conventional mining and retorting.

Most major developers have indicated that they intend to discharge no wastewaters directly to surface streams. Surface retorting process waters would be reused, and perhaps ultimately applied to retorted shale. Effects of extraction and processing activities on local hydrology and water quality are therefore likely to be indirect or incidental. The water pollution implications of mine dewatering, of creating large retorted shale disposal piles, and of abandoning in-ground retorts have not been determined; these actions could create major environmental impacts.

Because of the low concentration of compounds in discharge waters, no acute or chronic effects on aquatic biota in surface waters may result; however, compounds of low solubility may be bioaccumulated by some aquatic organisms and become toxic to other aquatic organisms, birds, and man. Oil shale process waters contain single-ring and polynuclear aromatics that contain suspected carcinogens. If process waters are discharged into the aquatic environment, sediments may accumulate these compounds and later release them slowly. Research is needed on the degradation of these compounds and on their potential for bioaccumulation in aquatic organisms.

Effects of extraction and processing activities on existing water quality in the oil shale region will vary with the geography and the season. Several streams and shallow aquifers provide water suitable for use in irrigation. In lower oil shale aquifers of the Piceance Basin and in the lower reaches of Piceance Creek, however, water quality exceeds the dissolved solids, fluoride, or boron criteria for domestic or irrigation use. On or near the Utah lease tracts (Ua/Ub), only the White River and the Bird's Nest aquifer contain significant amounts of water. Water in the White River is of suitable quality for use in irrigation except during low flow in the summer.

Withdrawing good quality surface water and ground water from sources in the upper Colorado Basin for consumptive use in oil shale processing may result in increased salinity levels in the lower Colorado River. The full effect of withdrawal on the Colorado River is not known. It is estimated, however, that an oil shale industry producing 1 million barrels (160,000 cubic meters) of shale oil per day will increase total dissolved solids between 10 and 27 milligrams per liter at Hoover Dam.

Aqueous wastes from oil shale processing can be categorized broadly as originating from direct or indirect sources. Wastewaters from direct sources are those generated by unit operations or processes, including:

- Retorting
- Upgrading
- Some air emission control and gas cleaning processes
- Cooling and boiler water blowdowns
- Water treatment
- Mine dewatering
- Sanitary disposal

Wastewaters from indirect sources include:

- Leachate from retorted shale disposal areas
- Runoff and erosion resulting from construction and site use
- Runoff resulting from mining and transport activities

water pollution is not unique to oil shale extraction and processing, but may require careful control because of the magnitude of site activities. Collection and impoundment of runoff will likely be necessary.

Solid Waste

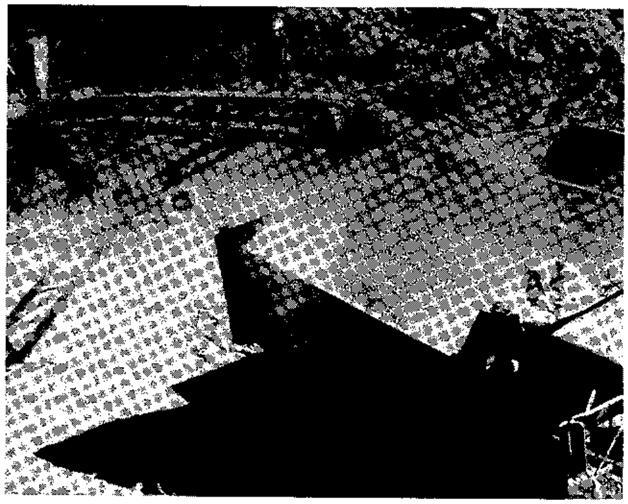
The solid wastes resulting from oil shale processing present one of the major environmental problems associated with commercial development. Shale-derived solid wastes will include fines from raw shale crushing and conveying, mined raw shale waste, and processed (or retorted) shale. Together these wastes constitute most of the process solids requiring disposal. Other solid wastes will depend primarily on the pollution controls employed and on the extent to which crude shale oil upgrading is carried out in conjunction with retorting. These wastes may include shale oil coke, treatment sludges, and spent catalysts.

Disposal of surface retorted shale will involve transport and surface emplacement of large quantities of solids on a scale only rarely attained to date in the mining industry. The spent shale will contain potentially leachable salts and, in some cases, a carbonaceous residue from retorting. If shale oil is upgraded in conjunction with retorting, a disposal pile might also contain spent catalysts, sludges, arsenic-laden solids, and other plant wastes.

In light of the foregoing, it would appear that potential hazards exist relating to:

- Pile stability
- Airborne particulates, odors, and organic vapors
- Leachates, organic and inorganic, caused by precipitation and ground water movement
- Transfer of possible hazardous organics or trace elements to the biosphere
- Translocations of toxic substances to vegetation

Mass movement of disposal piles could adversely affect water quality. Sediment and salts could be added to local surface waters, or to catchment structures. Changes in pile drainage systems caused by slumping, and so forth, may encourage infiltration.



Loading spent oil shale from the retort onto trucks, Anvil Points, Colorado

Vegetation may be difficult to maintain on a destabilized pile surface; as a result, surface wind and water erosion may increase.

Because no large disposal piles have been constructed to date, little is known about pile stability in real situations. Further, most of the work to date has dealt with carbonaceous shales; decarbonized shales, from which the organic content has been burned off, are likely to differ significantly in stability and leaching properties.

To control fugitive dusts, and to provide moisture for compaction and stabilizing the disposal piles, retorted shale will be wetted before transport and disposal. It is not known whether wetting will be sufficient to minimize particulate emissions at the scale of operations contemplated at each site. The characteristics of the spent shale and the micrometeorology at a given site are among the pertinent variables.

All criteria pollutants can be expected to be emitted from processing and combustion of shale oils. Arsenic and heteroatomic components of shale oils may also pose health problems.

Other Effects

Some radioactivity will be released to the atmosphere during oil shale mining and processing. Radioactive elements will be contained in dust emissions, fine particulate emissions, process water discharges, and leachate from spent shale disposal piles. Some radon gas will be released directly.

Noise will be created during oil shale development by processing plant construction and operation, community expansion, mining, and water reservoir operation, and by construction and operation of pipelines, transmission lines, roads, and railways. Because oil shale development sites are, characteristically, a reasonable distance from population centers, the impacts of noise are expected to be negligible.

Social and economic impacts of development are expected to be fairly severe because known oil shale reserve sites are remote and sparsely populated. Population centers in the oil shale area are basically rural. The introduction of oil shale development will significantly increase the numbers of people who use the towns, creating higher demands on local municipal services such as fire and police protection, schools, hospitals and health care, and on local utilities such as electricity, water, gas, and sewage treatment. The new industry will, however, also bring a higher financial base to the area by creating more primary and secondary employment and, therefore, will increase local tax revenues.

only a few parts per million compared to quantities of thermally generated NO_x. Thermally generated NO_x can best be controlled by demonstrated combustion modification techniques. If crude shale oil is used as process fuel, control of both SO_2 and NO_x emissions could be necessary if process heaters are needed to meet the same New Source Performance Standards as those for industrial boilers. Full hydrotreating would be more cost effective than flue gas treating, if on-site refining is included in the shale oil facility.

Hydrocarbon emissions will result from direct preheating of raw shale, and will need control. Thermal incineration is probably the method of choice.

Hydrocarbons and carbon monoxide resulting from incomplete combustion will be emitted by the boilers, furnaces, heaters, and diesel equipment associated with oil shale development. With proper maintenance, emissions from these sources are not considered large; however, high background levels have been reported in some areas, and any additional contributions from process operations will be a cause for environmental concern. Hydrocarbon and carbon monoxide emissions can be held to a low level by proper design, operation, and maintenance of external and internal combustion equipment.

Wastewater Treatment

The quantity and quality of water available, methods of water use, and disposal criteria will dictate the pretreatment, internal conditioning, and wastewater treatment necessary at each oil shale processing site. Wastewaters from oil shale processing will contain dissolved and suspended solids, oil, trace elements and metals, trace organics, toxics (carcinogens), dissolved gases, and sanitary wastes. The major wastewater sources are given on page 7.

Individual waste streams have not been characterized adequately to make firm treatment or control technology judgments regarding which unit processes should be applied to which waste streams. Nonetheless, some ideal processing schemes have been envisioned and discussed. The size of the treatment unit will depend on the wastewater volume to be treated at a specific site and on the concentrations of pollutants to be removed. The basic operating approach will be to concentrate the pollutants for ultimate disposal or containment so that clean water can be recycled or discharged.

Wastewaters that contain dissolved solids (more than 1,000 milligrams per liter) and suspended solids, and that are essentially free of oil and trace organics, can be collected and flow-equalized in large holding lagoons before treatment. Oily wastewaters (more than 10 milligrams of oil per liter) from all wastewater sources should be collected and processed by American Petroleum Institute (API) separators or similar equipment before receiving further treatment. Wastewaters contaminated with trace elements and metals should be essentially free of oil and dissolved solids to allow them to be treated separately. Trace organic wastewater volumes are not expected to be large, but these wastewaters will contain highly diverse types of organic pollutants. Toxic wastewater volumes are expected to be small, but advanced treatment and control will be needed for the concentrates collected. Specific controls and treatment will be necessary for wastewaters from scrubbers that absorb common oil shale process gases—such as hydrogen sulfide, ammonia, and carbon dioxide—before the water is reused or discharged. Sewage and water treatment plant releases should be considered for separate treatment and disposal.

The amounts and qualities of water to be expected from mine dewatering are not known, and they will depend on the site. In contrast to some earlier characterizations of surface retorting operations as large water consumers, true and modified in situ developments may produce a surplus of water that will have to be treated and discharged or reinjected into aquifers.

necessary to provide for collection, treatment, and reuse of this leachate.

Process-generated solid wastes—such as spent catalysts, lime sludges, coke, and other solids from water and wastewater treatment systems—may contain toxic substances. Disposal of these wastes by burying them in the spent shale pile would be likely to increase the levels of toxic pollutants in the spent shale leachate. It may be possible to dispose of some process wastes along with the spent shale if it is demonstrated that the wastes do not themselves produce a leachate or promote production of additional pollutants in the spent shale leachate. A preferred method of handling potentially toxic spent catalysts would be to return them to the manufacturer for regeneration and subsequent reuse.

It may be possible to dispose of surface-retorted spent shale by returning it to the mine, backfilling either with dry spent shale or with a spent shale slurry. Because of the potential for chronic leaching, it is recommended that spent shale not be returned to a wet mine; leachate problems would be more easily controlled on the surface than in a subsurface environment. Returning dry spent shale to a dry mine, however, would create support, decrease subsidence potential, and reduce surface spent shale storage by about 60 percent. In any case, mine disposal of spent shale should not be considered viable until it has been critically investigated to ensure that leachates will not degrade ground or surface waters.

Leachate will contain water-soluble organic and inorganic solids. Because of its expected poor quality, leachate from surface disposal piles will probably be collected behind dams constructed for the purpose and located slightly downstream of the toe of the pile. An impermeable base should underlie the pile, and drains should be included to pick up the leachate and discharge it at the collection point. For modified in situ oil shale operations, it will probably be necessary to minimize water flow through the retorts and collect and treat as necessary any leachate. Most of the ions present in leachate are also present in various flue gas desulfurization process liquids; therefore, it could be possible to use the leachate on site for removal of sulfur dioxide from flue gas streams of surface retorts. The leachate problem could also be reduced by leaching the soluble minerals from the raw shale feed before retorting and passing the retorted shale through a spent shale burner to remove residual carbon and organics.

Modified in situ retorting, conventional underground mining, and possibly true in situ retorting may pose fracturing and subsidence problems unless subsidence control technology is provided. For conventional underground mining, some control technology exists that could probably be modified and applied to the specific hydrologic and geologic environment of a particular underground oil shale mine. Backfilling mine voids with spent shale could provide additional support, though ground water pollution could be a concern. Special attention would be needed to avoid long-term problems from weakening of pillar strength by spalling and weathering. For modified and perhaps true in situ retorting, the key to controlling subsidence or fracturing of surrounding strata will probably lie in learning to control rubblization and in developing a technology that will provide pillars adequately sized and appropriately spaced to support overlying strata.

Other Controls

Other process controls include those necessary to reduce storage tank emissions, biological sludges, tank bottom sludges, and separator sludges. Floating-roof tanks and internal floating covers reduce both diurnal breathing losses and filling losses associated with fixed-roof tanks. The technology is well developed, having been used in the petroleum and chemical industries. Internal floating covers are preferable in sites having high wind, rainfall, or snowfall because they are protected from the weather.

Refineries limit or reduce sludges and other solid wastes primarily through source control. Source control techniques involve identifying and monitoring sources of oil, water, and other contaminants and then implementing inplant operating procedures to introduce less water into drains, to recover oil and water from solid wastes, to decrease the amount of contaminants in oily drainage, and to reduce the oil content of API separator solid waste.

Sampling, Analysis, and Monitoring

One problem facing developers is sampling and analysis of product and waste streams associated with producing oil from oil shale. The methods that have historically been used to analyze air and water samples have been applied to oil shale effluents, but without the straightforward results expected. Extraordinary interferences and matrix effects apparently make some methods ineffective. Many workers in the field are addressing the problem of standardization of methods for collecting, shipping, storing, and analyzing samples. Interlaboratory studies on many different types of environmental samples will be needed to validate those methods best suited for consistent analysis of oil shale pollutants.

Effective monitoring through sampling and analysis is expected to provide:

- A baseline evaluation of conditions before development
- A record of changes from baseline conditions
- A continuing check of compliance with environmental regulations and laws
- Predictive capability for timely notice of developing problems
- A check on the effectiveness of mitigating procedures

A monitoring program should include sampling of point source effluents at and around the facility, non-point-source effluents resulting from activity at the mining, processing, and disposal sites, and accidental discharges. Monitoring should begin with a baseline survey; it should continue for the life of the project and afterward as long as necessary to ensure compliance with environmental regulations and laws and lease stipulations.

An air-monitoring program should include on-site gas and particulate analyses and a network of meteorological and air quality measurement stations remote from the processing site. It should also include upper air studies and diffusion modeling to demonstrate and ensure compliance with Federal and State air quality standards.

Surface water monitoring should incorporate biological monitoring as well as physical and chemical analyses. Changes in aquatic biota may indicate subtle changes in water quality characteristics before they are detected by physical-chemical analyses for specific pollutants or by indicator parameters such as dissolved oxygen, pH, and hardness. Water monitoring should be done both upstream and downstream; wet and dry surface streams and springs and observation wells should be monitored to detect ground water changes.

In a water-monitoring program, non-point-sources will probably receive greater attention than point sources because of the difficulty of monitoring pollutants emanating from shale piles, construction sites, access roads, unlined catchments, and evaporation ponds. Adding to this problem will be the possible discharge of saline ground waters. Moreover, site activities may result in reduced water flows and, therefore, may affect already limited supplies of water for agriculture, livestock watering, and other beneficial uses.

In addition to spent shale, disposal sites will probably contain raw shale fines, spent catalysts, sludges, and process wastewaters. Surface erosion and leaching of soluble salts and organic compounds will necessitate extensive disposal site monitoring, particularly of revegetation trenches, of the alluvium, and at the toe of the pile where pollution is most likely. The spent shale monitoring program particularly should be designed to identify environmental problems in time for corrective measures to be taken.

Monitoring programs and long-term studies should also be undertaken for:

- Revegetation
- Terrestrial biology
- Game management
- Aquatic biology
- Soil mapping and analysis
- Toxicology
- Trace elements in the ecosystem
- Ecological interrelationships
- Visibility
- Scenic, archaeologic, paleontologic, and historic values