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Project Summary

Assessment of Solid Waste Characteristics and Control Technology for Oil Shale Retorting

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This work is a comprehensive study of the characteristics of solid and liquid wastes produced from various oil shale processing technologies, and control methods for environmentally safe disposal of solid wastes. It also includes results from an experimental study to construct liners and covers for proper disposal of spent shales. In addition the autoignition potential of raw and spent shales has been evaluated.

Oil shale deposits in the eastern and western parts of the U.S., their geological subdivisions, locations, tonnage, and physical and chemical characteristics have been described. The solid and liquid wastes generated from the various oil shale technologies have been compiled. Amounts of solid and liquid wastes generated and their composition depend, among other things, on the technology used and on the type of shale processed. Some of the wastes may also be site specific. Available field and laboratory leachate data are also presented.

If only 50% of the planned production comes on line, it would eventually amount to about 600,000 barrels/day (BPD)* of shale oil. This would lead to about 740,000 tons/day (TPD) or 270 million tons/year of retorted oil shale, along with lesser quantities of other solid wastes, which would require environmentally safe disposal. If not properly managed, these high volume wastes are capable of producing leachates that could contaminate the water supply for millions of people. Surface disposal sites covering many square miles in area and hundreds of feet in depth would do extensive property damage and threaten lives should they ever suffer sudden mass failure. An experimental program was undertaken to establish the best combination of spent shale with materials readily available at the disposal site to construct liners and covers for the spent shale disposal.

Also in this report available information has been compiled to evaluate the autoignition potential of raw and spent shales from various oil shale processes. The results indicate that raw shale fines have a potential for spontaneous ignition similar to bituminous coals, while such potential for retorted shales appears to be less. Hence, there is a potential that, if oil shale disposal sites are not properly designed, they could autoignite. It appears probable that control technology employed by the coal industry can be modified and applied to oil shale disposal sites to mitigate this hazard.

Control technologies to prevent serious adverse impacts from disposal of billions of tons of oil shale wastes have been proposed, but their application to oil shale waste materials on the scale required for commercial plants has not been demonstrated. Furthermore, to be effective, these control technologies must be applied to highly technical and integrated disposal designs that are site

*Readers more familiar with the metric system may use the conversion factors at the back of this Summary

and process specific. There is no current experience in disposal of wastes of similar composition or of volumes approaching that which will result from the oil shale industry.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

1985 marks the start of the commercial U.S. oil shale industry with the first commercial plant (Union Oil's 10,000 BPD Long Ridge facility) coming on line. Many additional and often much larger plants are scheduled to start production between 1987 and 1994, with many of the early plants being subsidized by the Federal Government through the U.S. Synthetic Fuels Corporation. If only 50% of the planned production comes on line, then about 740,000 TPD or 270 million TPY of retorted oil shale, along with lesser quantities of other solid wastes, will require environmentally safe disposal.

The types and quantities of solid waste that will be produced from proposed oil shale facilities are not yet well defined.

Although these projects are quite different in that they employ different retorting technologies, retort different grades of shale at different rates, produce differing amounts and types of final products and, at times, employ differing control technologies, the rates of solid wastes can be compared when examined on a common basis. The common bases used are mined shale (tons of wastes per thousand tons of mined shale, T/MT) and hydrotreated oil (tons of waste per million barrels of oil, $T/10^6$ bbl).

Factors were determined on the basis of shale mined and oil produced for 16 solid wastes. Using these factors, it is possible to calculate probable rates of various solid wastes produced based on projected mining rates and product oil production for the above-ground oil shale retorting facilities.

Characteristics of U.S. Oil Shale

The location, geology, composition, and physicochemical properties of oil shale resources in the U.S. have been described.

These oil shale deposits occur in four general locations: (a) the Tertiary (Eocene) deposits of the Green River formation in Colorado, Utah, and Wyoming; (b) the late Devonian and early Mississippian period marine shales of the central and eastern U.S., stretching from Michigan and Pennsylvania south through Indiana and Kentucky, to Texas; (c) the early Cretaceous and upper Triassic marine shales in Alaska; and (d) the small Tertiary shale deposits of Montana, Nevada, Idaho, and California.

Not all of these deposits are sufficiently rich in organic matter to be considered commercially attractive. Estimates place total known U.S. oil shale resources for oil shales yielding 10 gal. of oil per ton of shale at well over 2×10^{12} bbl. The Green River formation oil shales in Colorado, Utah, and Wyoming account for an estimated 90% of this total resource and are therefore regarded as being the most important commercially.

Solid Wastes and Their Characteristics for Oil Shale Retorting Processes

Solid wastes, amounts generated, and their characteristics for various oil shale retorting processes were studied. The following oil shale retorting processes were considered: Lurgi-Ruhrgas, TOSCO II, Paraho direct heating mode, Paraho indirect heating mode, Occidental modified *in situ*, T^3 retorting, Hytort, Geokinetics horizontal *in situ*, Superior circular grate, Union Oil A, Union Oil B, Union Oil SGR, Chevron STB, Allis Chalmers, and Dravo. The available information on solid wastes for these retorting technologies was gathered, and the best available information for each technology is presented in the main report. The extent of data availability varies substantially from process to process. The composition of solid wastes and their physicochemical properties, along with leachate data, are presented in a systematic format.

Potential Dangers to Human Health and the Environment from the Disposal and Reuse of the Wastes

Although oil shale facilities will produce huge volumes of solid wastes, the potential for reuse of the wastes is small. Some wastes such as spent catalysts could potentially be reclaimed and recycled back into the process. Elemental sulfur, removed by some air pollution control technologies, has a limited market potential; however, it remains to be demonstrated on a commercial scale that there are no trace impurities that would constrain its use. It is expected that hazardous wastes such as spent catalysts and some sludges will be disposed of in licensed hazardous waste facilities. However, one catalyst (unique to shale oil upgrading) is of particular concern: the arsenic guard bed catalyst, which contains 20% or more arsenic. No facilities exist to reprocess this spent catalyst, and environmentally safe disposal may be difficult to achieve. Other than the arsenic guard bed catalyst, the major unique dangers to health or the environment posed by oil shale facilities may be from the long term effects of on site disposal of millions of tons of retorted oil shale, raw oil shale waste, and other process wastes. Principal concerns in this regard may be summarized as:

1. Autooxidation/autoignition may be a serious problem if raw shale fines and/or carbonaceous spent shales are not disposed of in a manner to minimize this risk.
2. High inorganic salt loading and possibly organics in leachates from raw shale fines or spent shale could potentially have significant impacts on groundwater supplies in the area and on surface waters that supply millions of people (Colorado River). A related issue is the extent to which process wastewaters should be treated prior to codisposal with the retorted shale. Codisposal of spent catalysts and treatment sludges may also significantly impact the nature of leachates from disposal sites.
3. Infiltration of moisture into disposal sites from precipitation or from surface or groundwater intrusion could lead to sudden pile failure. Such failure could cause extensive property damage, threaten lives, and contaminate the drinking water supply for millions of people.

Present/Proposed Disposal Practices

The slate of solid wastes to be disposed and their chemical nature will vary in response to the nature of the raw shale feed, the retorting process employed, the plant design (including pollution control technologies), and whether raw shale oil is upgraded on site. The design of the solid waste disposal site as well as the selection and application of appropriate control technologies must be tailored to accommodate not only the quantities and nature of the wastes but also the characteristics of the disposal site. Alternative disposal practices and control technologies are generally well known. All have been proposed or considered by one developer or another though no developer has yet proposed a plan incorporating all the control features that might be desired into a design for solid waste disposal.

Key features for handling solid wastes produced by a surface retorting process are presented in the full report, with a discussion of the control technologies applicable to the disposal alternatives.

Use of Spent Oil Shale as a Liner Material at Spent Shale Disposal Sites

This study has considered the possibility of using a spent oil shale itself as a water barrier or "liner" beneath a spent oil shale waste embankment. Pertinent properties of unburned TOSCO II spent shale and an average mixture of Lurgi spent shale have been measured. Materials consisting of 10, 20, and 30% burned spent TOSCO shale admixed into unburned TOSCO II shale have also been considered. Two autoclave mellowed materials admixed into their respective unmellowed spent shales have also been studied.

This work indicated the difficulty of having both easy self-healing and low permeability of the unmellowed TOSCO materials and mixtures and perhaps also of the unmellowed Lurgi spent shale. Autoclave mellowing of the burned TOSCO material, however, produced a high plasticity index material that may be blended with the silty unburned TOSCO II spent shale to produce a liner having (at least in the short term) both low permeability and good self-healing possibilities. A similar attempt with the Lurgi spent shale was not successful due to the high permeability produced in the short term aging experiments.

Impacts of Disposal Alternatives on the Use of Oil Shale and Other Natural Resources

Due to the volume of solid wastes produced by an oil shale facility, these wastes must be disposed of on or near the plant site. In the case of open pit mines, huge amounts of overburden and subgrade oil shale will also require disposal. These wastes could be disposed of entirely on the surface as piles or canyon fills or could partially be returned to the mine. Either way the leaching potential of these wastes must be carefully controlled or leachates will seriously impair the quality and use of surface and groundwater supplies. Depending on the placement of these wastes they could also impair future access to other oil shale resources. Returning some of the retorted oil shale to an underground mine would be expensive and technically difficult but could actually increase the potential for resource recovery by facilitating mining of the support pillars.

Potential Utilization of Oil Shale Solid Waste

Oil shale solid wastes having some potential for utilization include retorted oil shale, raw shale fines, spent catalysts, elemental sulfur, and biological treatment sludges. Retorted oil shales, particularly decarbonized shales, have some limited potential for utilization on site. Decarbonized western oil shales possess a significant capacity to cement similar to low grade commercial cement. Hence a very limited amount of retorted shale may be used locally as a low grade cement substitute. Raw shale rejects and fines, from mining and raw shale preparation, could be processed in specially designed retorts or possibly formed into briquettes and processed in the regular plant facilities. Spent catalysts could potentially be reclaimed and reused in the upgrading process, though facilities to reclaim them do not presently exist. Some air pollution control technologies remove elemental sulfur which, if not contaminated by impurities, should have at least a limited market for agricultural use. Biological treatment sludges may be useful on site as soil conditioners for revegetation if they do not contain significant quantities of harmful contaminants. However, even if all the above wastes are utilized to the maximum extent possible, it will not make a significant impact on the amount of solid waste to be disposed of.

Conclusions

1. The oil shale industry will produce unprecedented volumes of solid waste consisting mostly of retorted oil shales, raw oil shale fines, overburden and subgrade ore, codisposed wastewater, and much smaller quantities of known hazardous wastes. Although the known hazardous wastes will be sent to licensed disposal or recycling facilities, the high volume solid wastes will be disposed of on or near the plant site. If not properly managed these high volume wastes are capable of producing leachates that could contaminate the water supply for millions of people. Some of the waste may also pose the hazard of autoignition unless proper controls are employed. Surface disposal sites covering square miles in area and hundreds of feet in thickness would do extensive property damage and threaten lives should they ever suffer sudden mass failure.
2. Control technologies to prevent serious adverse impacts from disposal of billions of tons of oil shale wastes have been proposed, but their application to oil shale waste materials and on the scale required has not been demonstrated. Further, to be effective, these technologies must be applied in highly technical and integrated disposal designs that are site and process specific. There is no current experience in disposal of wastes of similar composition or of volumes approaching that which will result from the oil shale industry.

Metric Conversions

Although EPA's policy is to use metric units in all its documents, certain nonmetric units have been used in this Summary for the reader's convenience. Readers more familiar with the metric system may use the following conversion factors.

Nonmetric	Times	Yields Metric
bbl	158.98	L
°F	5/9 (°F-32)	°C
ft	0.3048	m
ft^3	28.316	L
in.	2.54	cm
mi^2	2.59	km^2
psi	70.307	g/cm^2
ton	0.9072	tonne

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The complete report, entitled "Assessment of Solid Waste Characteristics and Control Technology for Oil Shale Retorting," (Order No. PB 86-198 371/AS; Cost: $28.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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