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Emissions From Synthetic Fuels Production Facilities

VOLUME I
EXECUTIVE SUMMARY

U.S. Environmental Protection Agency
Region VIII
Denver, Colorado

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EMISSIONS FROM SYNTHETIC FUELS PRODUCTION FACILITIES

VOLUME I
EXECUTIVE SUMMARY

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FOREWORD

The two volumes comprising this document present a study of emissions from synthetic fuel production facilities performed under EPA Contract No. 68-01-3535. The synthetic fuel production facilities include oil shale and coal extraction, oil shale processing, and coal gasification.

This report presents the best available information. Most of the data for the TOSCO II oil shale process have been previously published and represent widely accepted estimates for the process. Accepted published data for the Union Oil and Paraho oil shale processes are not presently available. The emissions from these processes were estimated in this report based upon similar processes and developer information. Accepted data for the Lurgi coal gasification process have been previously published. As more information on these processes is released, the contents of this report will be updated or subsequent reports will be conducted to present these data.

This work was conducted under the direction of Mr. Terry L. Thoem, Project Officer, Environmental Protection Agency, Region VIII, Denver, Colorado. This study is complemented by another Radian study, "Atmospheric Pollution Potential From Fossil Fuel Resource Extraction, On-Site Processing, and Transportation", EPA-600/2/76-064. The fuel resources considered in that report are coal, oil shale, oil, and gas.

ABSTRACT

This report was compiled to provide the Environmental Protection Agency with an assessment of multi-media pollutants from oil shale processing and coal gasification facilities.

The report examines oil shale and coal extraction methods in addition to fuel conversion processes. Three oil shale conversion processes are considered: the TOSCO II, Paraho, and Union Oil processes. The Lurgi process is considered for coal gasification. Process descriptions and module definitions are presented for each operation. Potential air emissions, water effluents, and solid wastes are then identified and quantified for each module. Emissions of trace elements and organics are determined qualitatively. An assessment of resources required to support the production facilities is also included.

The overall report is presented in two volumes. Volume I summarizes the objectives, the approach, and the results of the study. Volume II gives detailed descriptions of the methodology and the results.

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1.0 INTRODUCTION

A large portion of the Western United States contains vast quantities of coal and oil shale. More than 60% of the nation's strippable coal reserves and essentially all of the attractive oil shale reserves are found in the 6 state EPA Region VIII area. Technology for the conversion of oil shale and coal into synthetic fuels is currently being developed and assessed.

Production of synthetic fuels can result in discharges of pollutants to the environment from conversion facilities This study assesses emissions and effluent characteristics, energy recovery, ancillary energy requirements and raw material consumption involved in the production of synthetic fuels from coal and oil shale. The study specifically examines oil shale and coal extraction, oil shale processing, and coal gasification. Three oil shale conversion processes are studied. They are the TOSCO II process, the Paraho process, and the Union Oil process. The Lurgi gasifier is studied for coal gasification assessment.

2.0 OBJECTIVES

The major objective of this study is to identify and quantify potential pollutants from production facilities for oil shale processing and coal gasification. The operations studied include oil shale and coal extraction and sizing, oil shale retorting (TOSCO II, Paraho, and Union Oil processes), coal gasification (Lurgi process), and shale oil upgrading.

Resources required to support the synthetic fuel production facilities are also assessed. These resources include manpower, water, and ancillary energy.

3.0 APPROACH

To assess the various synthetic fuels processes, all readily available information sources were investigated. These information sources include the following:

- EPA studies and regulations, such as energy conversion studies and new source performance standards,
- other government studies dealing with energy conversion systems, such as Federal Energy Administration, Council on Environmental Quality, Energy Research and Development Administration, and Department of the Interior,
- publications and private industry communications.
- information retrieval networks,
- site visits to pilot plant facilities, and
- Radian inhouse files.

After all the applicable information had been extracted from the above information sources it was apparent that sufficient information did not exist to adequately assess all the areas of interest. In areas where data were inadequate to quantify the pollutants from the synthetic fuels processes, similar processes were studied. For example, very little information is available on air emissions from the Union Oil and Paraho oil shale processes while a detailed assessment of the emissions from the TOSCO II process is available. An estimate of the emissions from the Union Oil and Paraho processes was made by comparing similarities in the operating parameters of these processes with those of the TOSCO II process. Where operating characteristics are dissimilar, similar operations from other industries, such as the petroleum refining industry, were assessed. Additional information on the emissions from the Union Oil process was obtained from the developer.

Insufficient data is available to quantify emissions of trace elements, such as selenium, mercury, lead, arsenic, cadmium, beryllium, and antimony, and trace organics, such as benz(a)pyrene. These trace pollutants are of special interest due to their demonstrated adverse health effects. A qualitative determination of trace pollutants from synthetic fuel processes was made by comparing trace pollutant studies for different operations and assessing the similarities and differences between the operations.

After the necessary information was gathered, a series of standardized modules representing the basic process steps were defined. Emissions and effluents, process energy, ancillary energy and raw material requirements were then quantified for each module. Module sizes were selected to represent "typical" commercial installations currently being considered for construction The oil shale modules are sized to produce 8,000 m^3/day (50,000 bbl/day) of primary fuels. The coal gasification module is sized for 8 x 10^6 Nm^3/day (250 x 10^6 scfd) of synthetic natural gas. The modules each produce about 7 x 10^{10} kcal/day (3 x 10^{11} Btu/day). Consequently, emissions from the conversion facilities can easily be compared on the basis of energy production rates.

Before making such a comparison, however, the following precautions should be observed:

1) Energy production rates for the modules are only approximately equal. Comparisons of emissions on the basis of energy production rates are intended to be used only as general guidelines.

2) The inherent value of products from the processes may be different. The primary fuel produced from oil shale is liquid, while fuel produced from coal gasification is gaseous. These fuels are not equally suitable for all applications. For example, liquid fuels are presently more appropriate for use in the transporation industry.

4.0 RESULTS

This section presents a summary of the emissions, effluents and solid wastes from the synthetic fuels production facilities studied. The pollutant rates from the facilities are compared and discussed.

4.1 Air Emissions

The impact of a synthetic fuel process is the sum of the impacts of the modules that make up that process. A summary of the emissions from the analyzed modules is presented in Table 4-1. The term "hydrocarbons" in this report refers to volatile organic emissions.

Mining

The oil shale surface mining module generates more pollutants than the room-and-pillar oil shale mining and the coal surface mining modules. Particulate emissions for oil shale surface mining are mainly due to the large amount of overburden that must be removed to expose the resource. For coal surface mining, a smaller quantity of overburden needs to be removed per energy equivalent of resource recovered. Nitrogen oxide, hydrocarbon, and carbon monoxide emissions from oil shale surface mining are significantly larger than from oil shale room-and-pillar mining. This is primarily due to the assumption that surface mining uses mostly diesel power while room-and-pillar mining uses significant amounts of electric power.

TABLE 4-1. MODULE AIR EMISSION SUMMARIES

	Module	Emissions (kg/day)				
		Particulates	SO_2	NO_x	HC	CO
1.	Oil Shale-Surface Mining	31,010	2,640	35,990	4,170	21,590
2.	Oil Shale-Room-and-Pillar Mining	665	--	2,945	590	5,180
3.	Oil Shale-Primary Sizing	245	--	--	--	--
4.	Oil Shale-Secondary and Tertiary Sizing	486	--	--	--	--
5.	Oil Shale-TOSCO II Retorting	7,652	1,587	15,557	2,948	508
6.	Oil Shale-TOSCO II Upgrading	190	1,490	1,378	7,659	168
7	Oil Shale-Paraho Retorting	988	1,244	12,407	265	425
8.	Oil Shale-Paraho Upgrading	190	1,490	1,378	7,659	168
9.	Oil Shale-Union Oil Retorting	683	1,528	6,788	325	715
10.	Oil Shale-Union Oil Upgrading	190	460	1,378	7,659	168
11.	Coal Surface Mining	3,794	83	1,125	130	676
12.	Coal-Lurgi High-Btu Gasification	790	10,970	17,930	210	N/A
13.	Coal-Lurgi Low-Btu Gasification	790	10,100	17,930	210	N/A
14.	Coal-Lurgi Medium-Btu Gasification	790	9,740	17,930	210	N/A

N/A - Not available

Oil Shale Retorting

The TOSCO II retort indirectly heats oil shale by using heated solids (ceramic balls). The Paraho retort and Union Retort B are assumed to indirectly heat oil shale with heated recycle gas.

Emissions from TOSCO II retorting and Paraho retorting are very similar except for particulates and hydrocarbons. TOSCO II emits more particulates because the oil shale is more finely crushed and because of an additional heat exchange step for heating the raw oil shale prior to retorting. This heat exchange step is probably also the cause of higher hydrocarbon emissions from TOSCO II. The Union Oil emissions are similar to the Paraho emissions except for NO_x. Lower NO_x emissions could result from Union Oil's plans to combust only fuel gas for retorting, while the other processes may also use fuel oil and C_4 liquid.

Oil Shale Upgrading

Different retorting methods produce different qualities of fuel. Since all the retorting methods are assumed to use indirect heat, the fuels produced that are available for process heat are very similar. Consequently, the upgrading emissions for the processes should be very similar. SO_2 emissions from the Union upgrading steps are less than for TOSCO II and Paraho since Union has no SO_2 emissions from the sulfur recovery unit because the tail gas is sent to the retorting unit to be combusted.

Coal Gasification

Emissions from Lurgi high-, medium-, and low-Btu gasifiers are very similar for the same energy output. Differences in the processes do not have a large impact on emissions. Gas production rates for the modules, however, are different. The high-Btu gasifier module is sized for a typical commercial facility. The medium-, and low-Btu gasifier modules produce higher gas rates to achieve the same energy output.

Summary

Total air emissions from synthetic fuel facilities, based on the sum of the modules, are presented in Table 4-2. In general, oil shale facilities have higher emission rates than coal gasification facilities except for SO_2 emissions. Surface mining modules of the oil shale facilities contribute the greatest amounts of emissions.

4.2 Water Effluents

All of the synthetic fuels processes examined are based on zero discharge of water effluents to the surface water. This design feature has not been established at full scale facilities. Also, the potential impact from the leaching of pollutants into ground water systems, has not yet been defined.

4.3 Solid Wastes

The amount of solid waste produced by each module is presented in Table 4-3 along with a description of the waste. Surface mining of coal and oil shale produce significant amounts

TABLE 4-2. SYNTHETIC FUEL FACILITY AIR EMISSION SUMMARIES

Process	Emissions (kg/day)				
	Particulates	SO_2	NO_x	HC	CO
1. Oil Shale-Surface Mining/TOSCO II	38,852	5,717	52,925	14,777	22,266
2. Oil Shale-Surface Mining/Paraho	32,188	5,374	49,775	12,094	22,183
3. Oil Shale-Surface Mining/Union Oil	31,883	4,628	44,156	12,154	22,473
4. Oil Shale-Room-and-Pillar/TOSCO II	8,507	3,077	19,880	11,197	5,856
5. Oil Shale-Room-and-Pillar/Paraho	1,843	2,734	16,730	8,514	5,773
6. Oil Shale-Room-and-Pillar/Union Oil	1,538	1,988	11,111	8,574	6,063
7. Coal-Surface Mining/Lurgi High-Btu	4,584	11,053	19,055	340	676*
8. Coal-Surface Mining/Low-Btu	4,584	10,183	19,055	340	676*
9. Coal-Surface Mining/Medium-Btu	4,584	9,823	19,055	340	676*

*Includes only CO emissions for coal surface mining.

TABLE 4-3. SOLID WASTE

Module	Solid Waste (Metric Tons/Day)	Composition
1. Oil Shale-Surface Mining	65,000	Overburden
2. Oil Shale-Room-and-Pillar Mining	---	---
3. Oil Shale-Secondary and Tertiary Sizing	---	---
4. Oil Shale-TOSCO II	49,380	Processed shale/softener sludge/spent catalyst
5. Oil Shale-Paraho	49,380	Processed shale/softener sludge/spent catalyst
6. Oil Shale-Union Oil	48,500	Processed shale/softener sludge/spent catalyst
7. Coal-Surface Mining	42,700	Overburden
8. Coal-Lurgi High-Btu Gasifier	5,940	Gasifier ash/softener sludge/spent catalyst
9. Coal-Lurgi Low-Btu Gasifier	5,470	Gasifier ash/softener sludge/spent catalyst
10. Coal-Lurgi Medium-Btu Gasifier	5,280	Gasifier ash/softener sludge/spent catalyst

of overburden waste material. Oil shale processing also generates large quantities of solid waste. Disposal of processed shale may be a significant problem unless careful processed shale management is undertaken. The slightly smaller solid waste generation by the Union Oil process is solely due to the assumption that the Union Oil process uses a higher grade oil shale. This assumption is based on available data for the processes.

4.4 Trace Elements

Quantitative information on trace elements from oil shale processing and coal gasification is currently unavailable. Consequently, the fate of trace elements is qualitatively discussed.

Oil Shale Processing

Information on the fate of trace elements from processes similar to oil shale processing was assessed. A chemical equilibrium program was used to predict the behavior of trace elements in oil shale processing. The results show that the following trace elements are expected to volatilize in the oil shale retort:

antimony	cadmium	mercury
arsenic	germanium	selenium
boron	lead	tin

These trace elements will tend to become enriched in the shale oil. Thus, while most of the trace elements will be removed in subsequent shale oil processing, these trace elements will become air emissions when the shale oil is refined or combusted.

The study also indicates that the following trace elements tend to stay in the processed shale:

barium	copper	nickel
beryllium	manganese	uranium
chromium	molybdenum	zinc
cobalt		

These trace elements may be leached from processed shale and enter ground water systems if the processed shale is improperly disposed.

Coal Gasification

Available information on the fate of trace elements from coal gasification and processes with similar operating conditions was assessed. Studies including the Equilibrium Program predict that the following trace elements volatilize in the gasifier:

antimony	fluorine	phosphorus
arsenic	lead	selenium
bromine	mercury	tellurium
cadmium		

These trace elements will tend to become enriched in the synthesis gas. Subsequent processing of the synthesis gas may remove some of these elements, but those that remain will become air emissions as the gas is combusted as fuel.

The studies also indicate that the following trace elements tend to remain in the gasifier ash:

barium	copper	tin
beryllium	manganese	uranium
cadmium	molybdenum	vanadium
chromium	nickel	zinc
cobalt		

These trace elements may be leached from ash and enter ground water systems if the gasifier ash is disposed of improperly.

4.5 Trace Organics

Quantitative information on trace organics such as benz(a)pyrene from oil shale processing and coal gasification is currently unavailable. Therefore, the fate of these trace organics is qualitatively discussed.

Oil Shale Processing

Fugitive air emissions of trace organics such as polycyclic aromatic hydrocarbons, including benz(a)pyrene, are a potential problem in oil shale processing. There is no data, however, to indicate that these fugitive emissions are any worse than those incurred at a petroleum refinery.

A potential problem exists that is unique to processed oil shale disposal. Preliminary studies indicate that benz(a)-pyrene is present in processed shale and can be leached from carbonaceous deposits on processed shale by saline water. This indicates that trace organics such as benz(a)pyrene may be introduced into ground water systems if processed shale is improperly disposed.

Coal Gasification

Data on trace organics from coal gasification is inadequate. However, examination of similar processes such as coal combustion and coal coking indicate that trace organics such as benz(a)pyrene are likely to be present in coal gasifier tars. There is also the possibility that trace organics may enter the cooling water system through heat exchanger equipment leaks. They would then be concentrated and emitted from the cooling system.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions result from this study:

1) For equivalent energy outputs, oil shale processing facilities using surface mining emit greater quantities of hydrocarbons, particulates, NO_x, and CO than coal gasification facilities.

2) Oil shale surface mining is the greatest source of particulates, NO_x, and CO. Particulate and NO_x emission rates for oil shale facilities using room-and-pillar mining are reduced to levels similar to coal gasification facilities.

3) Of the oil shale processes studied, the TOSCO II process has the highest emission rates of hydrocarbons and particulates.

4) SO_2 emissions are higher from coal gasification facilities than oil shale processing facilities.

5) Air emissions and water effluents may contain trace elements and organics from both oil shale processing and coal gasification.

6) The quantity of solid wastes produced in the process is large, especially for oil

shale processing. Improper disposal of processed oil shale and coal gasifier ash may result in the leaching of trace elements and organics into ground water systems. Processed oil shale, in particular, may be a source of benz(a)pyrene.

7) Water effluents from the processes will be negligible if they are operated in the "zero discharge" mode. "Zero discharge", however, has not yet been demonstrated on a commercial scale.

As a result of the study, the following recommendations for future work have been identified:

1) Sampling of EPA criteria pollutants from all the systems studied is recommended. Pilot plant and prototype operations should be sampled before a widespread industry is developed.

2) The data are insufficient on trace element and organic emissions and effluents for all the processes studied. Data should be gathered from existing facilities. A sophisticated sampling plan should be developed to ascertain the ultimate fate of these pollutants in the environment.

3) The assumption of "zero discharge" of water effluents from the synthetic fuels processes is a critical parameter in

this study. The credibility of the basis of this assumption should be established for the processes by further modeling of the aqueous water systems to establish an optimum water reuse strategy. The merit of treating effluents to a quality that may be discharged should also be investigated. Facilities will be located in water-short areas. Removal of water for plant consumption will deplete surface streams. The resultant increase of total dissolved solids in the streams may produce an environmental impact.

4) The environmental impact of alternate synthetic fuels processes such as in-situ oil shale recovery and coal gasification should be assessed and compared with more conventional methods.

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ERRATA

EPA-908/4-77-010A   Emissions from Synthetic Fuels Production Facilities - Volume I

Executive Summary

Table 4-1   Module Air Emissions Summaries   p. 7

1. Oil Shale Surface Mining

	Emissions (Kg/day)
Particulates	5038
SO_2	640
NO_x	8700
HC	1000
CO	5200

Table 4-2   Synthetic Fuel Facility Air Emission Summaries   p-10

	Emissions (Kg/day)				
	Particulates	SO_2	NO_x	HC	CO
1. Oil Shale-Surface Mining/ TOSCO II	13,611	3,717	25,635	11,607	5,876
2. Oil Shale-Surface Mining/ Paraho	6,461	3,374	22,485	8,924	5,793
3. Oil Shale - Surface Mining/ Union Oil	6,156	2,628	16,866	8,984	6,083

EPA-908/4-77-010B   Emissions from Synthetic Fuels Production Facilities - Volume II Report

Table 2.1-2   Summary of Environmental Impact from Surface Mining of Oil Shale-p.9

	Particulates	SO_2	NO_x	HC	CO
Air emissions (Kg/day)	5,038	640	8,700	1,000	5,200

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION VIII
1860 LINCOLN STREET
DENVER, COLORADO 80203

Dear Colleague:

I am transmitting the enclosed report "Emissions from Synthetic Fuels Production Facilities" (EPA-908/4-77-010A) for your information and use. This report is one of a series of publications resulting from programs administered and performed by the EPA Office of Energy Activities. The enclosed report was performed by the contractual agreement with Radian Corporation. Special credit is recognized to the EPA Office of Energy, Minerals, and Industry for providing the funding for this project. The subject report is published in two parts---an executive summary and a fully detailed report.

The study was initiated in order to provide the EPA with an assessment of the multi-media pollutants emanating from oil shale and coal gasification facilities and their associated resource extraction activities. Three oil shale conversion processes--TOSCO II, Paraho, and Union--are investigated. The Lurgi coal gasification process is studied. Extraction processes studied include both surface and underground operations. Process descriptions, resource characteristics, in addition to the potential air emissions, (including fugitive losses) water effluents and solid wastes generated are presented in the report. Emissions of trace inorganic elements and organic compounds are presented. Net energy efficiency has also been calculated and discussed. An attempt to relate ambient air or water quality concentrations has not been performed.

Availability, reliability, and accuracy of data pertaining to this study was difficult to assess, but in general it was felt that the information included in this report was the most current as of early 1977. Since that time other oil shale processes including the Superior

1977. Since that time other oil shale processes including the Superior multi-mineral recovery and the modified in-situ process have been promoted for potential commercialization. These processes should be the subject of a similar analysis such as is performed in the enclosed report.

Conclusions which may be drawn from this study include......

1. For equivalent energy outputs, oil shale processing facilities using surface mining emit greater quantities of hydrocarbons, particulates, NO_x, and CO than coal gasification facilities.

2. Oil shale surface mining is the greatest source of particulates. NO_x, and CO. Particulate and NO_x emission rates for oil shale facilities using room-and-pillar mining are reduced to levels similar to coal gasification facilities.

3. Of the oil shale processes studies, the TOSCO II process has the highest emission rates of hydrocarbons and particulates.

4. SO_2 emissions are higher from coal gasification facilities than oil shale processing facilities.

5. The environmental impact of alternate synthetic fuels processes such as in-situ oil shale recovery and coal gasification should be assessed and compared with more conventional methods.

If you should have any questions regarding this report please contact me or members of my staff. For additional copies of this report or for information regarding other publications resulting from the Office of Energy Activities Energy/Environment Program please contact Ms. Betty Thalhofer (303-837-5914) of my staff.

Sincerely,

Cooper H. Wayman
Director
Office of Energy Activities

Enclosure