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Project Summary

Environmental Aspects of Synfuel Utilization

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This study reviews the environmental concerns relating to the distribution, handling, and end use of synfuel products likely to enter the marketplace by the year 2000, and assigns priority rankings to these products based on environmental concerns to aid EPA in focusing its regulatory and research activities. Major products and by-products from oil shale, coal liquefaction, and coal gasification technologies are considered.

Based on current developmental activities, three likely scenarios for shale- and coal-based synfuel plant buildup are projected. The type and quantity of synfuel products and by-products likely to enter the market are identified and their regional market penetration is estimated. The environmental analysis consists of a review of the available data on the physical, chemical, and health effects characteristics of synfuel products and environmental significance of their characteristics; an analysis of the potential environmental impacts and regional implications associated with the production and use scenarios considered; and a ranking of the products from the standpoint of environmental concerns and mitigation requirements.

The results indicate that: (1) significant quantities of synfuel products are expected to enter the marketplace during the next 20 years; (2) large-scale transportation, distribution, and end use of certain synfuel products can present significiant threats to the environment and the public health; (3) based on gross characteristics, synfuel products appear to be similar to petroleum products, but detailed characterization data are not available with which to judge their relative safety; and (4) synfuel test and evaluation programs currently underway or planned provide excellent opportunities for collecting some of the required environmental data.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Tri angle 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

The present study consists of: (1) a projection of synfuel production and product utilization over the next 20 years, and (2) a ranking of products from the standpoint of environmental concerns. The data base used consists of information obtained from major process developers, potential product users, and published literature.

Candidate Technologies and Products

Synfuel technologies likely to be used in commercial plants over the next 20 years are oil shale, coal gasification (low-/medium-Btu and SNG) and coal liquefaction (direct and indirect). Brief descriptions of these technologies and their development status are presented

in Table 1. Major products and by-products of these technologies and their anticipated general uses are indicated in Figure 1.

Synfuel Energy Buildup Scenarios

Three scenarios or forecasts for synfuel industry buildup to the year 2000 were developed. These scenarios are:

- National goal scenario driven by federal incentives (Scenario I; medium buildup rate).
- Nominal production scenario (Scenario II; low buildup rate).
- Accelerated production scenario representing an upper bound for industry buildup (Scenario III; high buildup rate).

The scenarios project the total quantities of shale oil, low-/medium-Btu gas, high-btu gas, and liquids from coal that would be expected to enter the market under the assumed sets of conditions. Based on discussions with major synfuel suppliers and users and industry and government planners, Scenario II was selected as the most realistic of the three scenarios and was used for analysis of regional impacts and environmental issues. This scenario is consistent with the general consensus among technical experts and potential major suppliers that shale oil is most nearly cost competitive and closest to commercialization than high-Btu gasification or coal liquefaction, and that commercial coal liquefaction facilities will not probably come on-line before the early 1990's.

Table 2 presents the product/by-product estimates of synfuel utilization in the U.S.

Note that, even though on a national scale, projected synfuel utilization would account for small fractions of the total product usage, in some regions a very high fraction of the currently used products are expected to be replaced by synfuel products.

Synfuel Product Utilization and EPA Regions of Maximum Impact

EPA regions where synfuel products would most likely be utilized are identified in Figure 2. Except for oil shale in the 1988-1992 and 1993-2000 time frames and for direct coal liquefaction in the 1993-2000 time period, the transportation, distribution, and use of products are expected to be confined to the regions where each synfuel is produced. Consequently, environmental impacts associated with product utilization are expected to be confined primarily to the production regions, except for impacts associated with the natural transportation of pollutants across regional boundaries (for example, transportation of air pollutants emitted from combustion sources). The projections indicate that up to the year 2000 under Scenario II, the environmental impacts of synfuel product utilization would be expected to be largely limited to EPA Regions V and VIII for oil shale; to EPA Regions IV, VI, and VIII for medium-Btu gas; to EPA Regions III, IV, and VIII for indirect coal liquefaction products; and to EPA Regions III, IV, and V for direct liquefaction products.

Environmentally Significant Characteristics of Synfuel Products

The current product characterization data base is a collection of results of sampling, analysis and performance testing conducted by different investigators using samples/batches of products obtained from pilot plants operated under varying conditions. Accordingly, significant inconsistencies exist in the reported results, which further hamper assessment of the environmental safety of synfuel product utilization. This assessment is also hindered by a lack of data on analogous petroleum and natural gas products that the synfuel products will replace and that, because of their large-scale and widespread utilization, have generally come to be viewed by the public as environmentally innocuous.

Table 1. *Candidate Synfuel Technologies and Their Status of Development*

Technology	Description	Development Status
Oil Shale	• Heating oil shale to about 480°C to extract shale oil • Heating by surface retorting, in-situ retorting, or modified in-situ retorting • Crude shale oil can be upgraded to produce syncrude for use as refinery feed stocks or boiler fuel	• Closest to commercialization of all synfuel technologies for production of large volumes of liquid fuels • Surface retorting more advanced than in-situ retorting • All technologies demonstrated at pilot scale or larger • Several production facilities planned for operation in 1980's
Direct Coal Liquefaction	• Coal, hydrogen, and a coal-derived liquid mixed at high temperature and pressure to produce additional coal-derived oil, which is separated and refined to liquid fuels • Three major processes under development: SCR II, H-coal, and Exxon Donor Solvent (EDS). Processes differ in the way hydrogen is made to react with coal	• SRC II: Pilot plant under operation; 6700-ton/day of coal demonstration unit under design and scheduled for operation in 1984-85 • H-Coal; 600-ton/day of coal pilot plant under construction; testing to begin soon • EDS: 250-ton/day of coal pilot unit under construction; testing to begin soon
Indirect Coal Liquefaction	• Coal reacted with oxygen and steam in a gasifier to produce a synthesis gas; after removal of CO_2 and other impurities, CO and H_2 in the gas reacted catalytically to produce several products ranging from lightweight gases to heavy fuel oil (Fischer-Tropsch process) or to methanol which is then converted to gasoline (Mobile-M process)	• Fischer-Tropsch: 8000-ton/day of coal plant (SASOL I) producing over 10,000 bbl/day of liquids in commercial operation since 1956 in South Africa; a 40,000-ton/day of coal unit (SASOL-II) will begin operation soon • Mobil-M: Commercial plant to produce 12,500 bbl/day of gasoline from reformed natural gas planned for New Zealand in 1984-85
Coal Gasification	• Reacting coal, steam, and air/oxygen to produce low-Btu (80-150 Btu/scf) or medium-Btu (300-500 Btu/scf) gas; medium-Btu gas purified and upgraded to SNG (~1000 Btu/scf) • Gasifiers differ in design and operation, depending on type of coal used and products desired	• Low-Btu gas: Extensive commercial experience in U.S. with gasifiers operating near atmospheric pressure; applications are small-scale operations producing gas for captive use in industrial and process heating • Medium-Btu gas: extensive commercial experience exists for Lurgi fixed-bed process; several projects using the Texaco process for captive applications (chemical feedstocks and on-site power generation) in planning and design stages • High-Btu gas: plans for SNG production using Lurgi technology announced by pipeline and gas utility companies

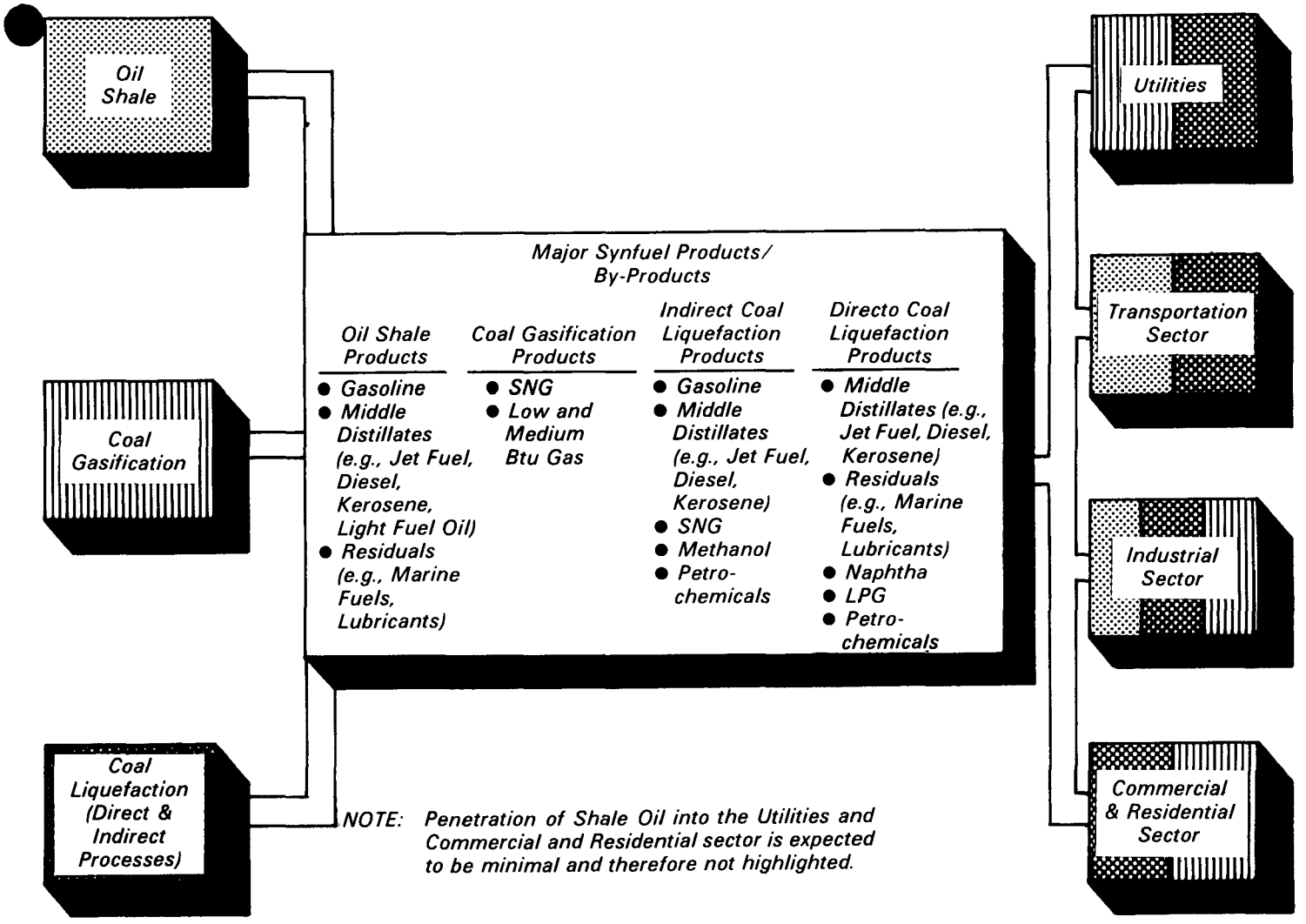

Figure 1. *Synfuel utilization during 1985-2000.*

Table 3 identifies the differences in chemical, combustion, and health effects characteristics of synfuel products and their petroleum analogs, based on the reported characterization data. These differences primarily relate to the higher content of aromatics and fuel bound nitrogen (FBN) and greater emissions of NO_x during combustion. Although no test data for synfuel products are available, high concentrations of aromatics in fuels have been shown to enhance production of PNA's during combustion. In the case of fuels, high aromaticity has been generally implicated in an increase in smoke production; the limited combustion data which are currently available, however, do not indicate that all aromatic synfuels have higher smoke levels. High FBN content can raise the level of NO_x emissions; the excess NO_x emissions of synfuels are believed to be correctable by combustion modifications. The nitrogen content of the synfuels can also be lowered to meet appropriate fuel specifications by the use of certain refining processes.

The data in Table 3 identify two products as highly hazardous because of mutagenic, tumorigenic, and cytotoxic properties. These are crude shale oil and fuel oils from coal liquefaction processes. These hazardous properties, which are characteristic of high boiling and tarry coal and petroleum materials, are caused by the presence of substances or classes of substances such as polycyclic aromatic hydrocarbons, hetero- and carbonyl-polycyclic compounds, aromatic amines, and certain inorganics (for example, arsenic in crude shale oil).

In general, synfuel product characteristics that cause environmental concern in any wide-scale utilization scenario relate to the known or potential presence of toxic substances (including carcinogenic compounds associated with crude shale oil and heavy distillates from coal liquefaction and hazardous aromatics), fuel-bound nitrogen, volatile components, and minor and trace elements. Potential environmental concerns relating to anticipated product uses generally fall into three categories: occupational exposure, public exposure, and general environmental pollution. The occupational hazards affect workers manufacturing and using the products and personnel involved in facility maintenance and product distribution

Table 2. Estimated Quantity of Synfuel Products used in the U.S. Under Scenario II

Product	1980-1987		1988-1992		1993-2000	
	Amount (10^6bpd)	% of total in U. S.	Amount (10^6 bpd)	% of total in U. S.	Amount (10^6 bpd)	% of total in U.S.
Crude shale oil (fuel)	0.0008	0.05	0	0	0	0
Shale oil refinery feed	0.07	0.45	0.41	0.24	0.43	2.4
Shale jet fuel	0.015	1.2	0.09	6.5	0.09	6.8
Shale diesel fuel	0.042	1.2	0.23	6.5	0.23	6.8
Shale residuals	0.007	0.2	0.04	1.3	0.04	1.3
Shale gasoline	0.13	0.2	0.07	0.9	0	0
Medium-Btu gas (coal)	0.09	0.9	0.27	2.8	0.45	4.7
SNG (coal)	0.042	0.4	0.17	1.8	0.25	2.6
Gasifier tars, oils	0.004	0.04	0.01	0.1	0.01	0.1
Gasifier phenol	0.004	0.04	0.01	0.1	0.02	0.2
F-T LPG	0	0	0.01	0.06	0.01	0.06
F-T medium-Btu gas	0	0	0.01	0.06	0.01	0.1
F-T SNG	0	0	0.03	0.33	0.07	0.7
F-T heavy fuel oil	0	0	0.001	0.02	0.001	0.03
F-T gasoline	0	0	0.02	0.2	0.03	0.4
Mobil-gasoline	0	0	0.05	0.66	0.1	1.3
F-T diesel fuel	0	0	0.002	0.04	0.01	0.1
Fuel methanol	0	0	0.14	1.8	0.23	3.0
SRC II fuel oil	0	0	0.03	0.3	0.09	1.3
SRC II naphtha	0	0	0.02	0.2	0.05	0.8
SRC II LPG	0	0	0.006	0.4	0.02	1.6
EDS fuel oil	0	0	0	0	0.06	1.0
EDS naphtha	0	0	0	0	0.03	0.6
EDS LPG	0	0	0	0	0.01	0.9
H-coal fuel oil	0	0	0	0	0.06	0.4
H-coal naphtha	0	0	0	0	0.03	0.2
H-coal LPG	0	0	0	0	0.01	0.1

services. Public exposure primarily relates to air pollution resulting from product uses such as the use of gasoline in automobiles, hazardous fugitive emissions from storage tanks and product transfer points, and accidental spills. In the general category of environmental pollution, major contributors would include accidental spills, sludges from product storage tanks and spill cleanup, and solid, liquid, and gaseous wastes associated with combustion and combustion-related air pollution control.

Basis for Priority Ranking of Synfuel Products

As noted previously, the objective of the study was to provide input to the EPA effort for: (1) assessing the environmental implications of a mature synfuel industry and of large-scale utilization of synfuel products; and (2) planning and prioritizing regulatory and research and development programs. Accordingly, a system was developed and used to rank the synfuel products from the standpoint of environmental concerns and to identify those products and areas of concern that should receive more immediate and greater regulatory and R&D attention. The ranking is subject to the limitations of the existing product characterization data and the assumptions used in developing the productions and use scenarios; the product rankings will most likely change as more data become available, especially for those products for which little or no data are currently available. It should also be noted that the specific approach used represents only one of many approaches that could be used to rank synfuel products from the standpoint of environmental concerns.

Two approaches were examined for ranking the synfuel products, based on: (1) the limited product characterization data currently available (Table 3) supplemented by engineering judgement where appropriate; and (2) the premise that, in the absence of detailed characterization data, and unless the available data indicate otherwise, it would be reasonable to assume that a synfuel product would be more hazardous than its petroleum analog. The first approach was selected and used to develop product rankings.

Under this approach, a synfuel product would necessarily be considered more hazardus because of the mere lack of detailed characterization data. Instead, assignment of a more positive ranking to a product is supported by actual data or is based on strong indications of greater potential hazards. Under the first scenario, prioritization of regulatory and R&D activities does not have to await collection of additional data, which should proceed concurrently as a separate effort.

Attribute Rating Procedure

Table 4 presents the assessment of the environmental concerns for various synfuel products relative to their petroleum analogs on a "barrel-per-barrel" basis. As indicated by the headings in

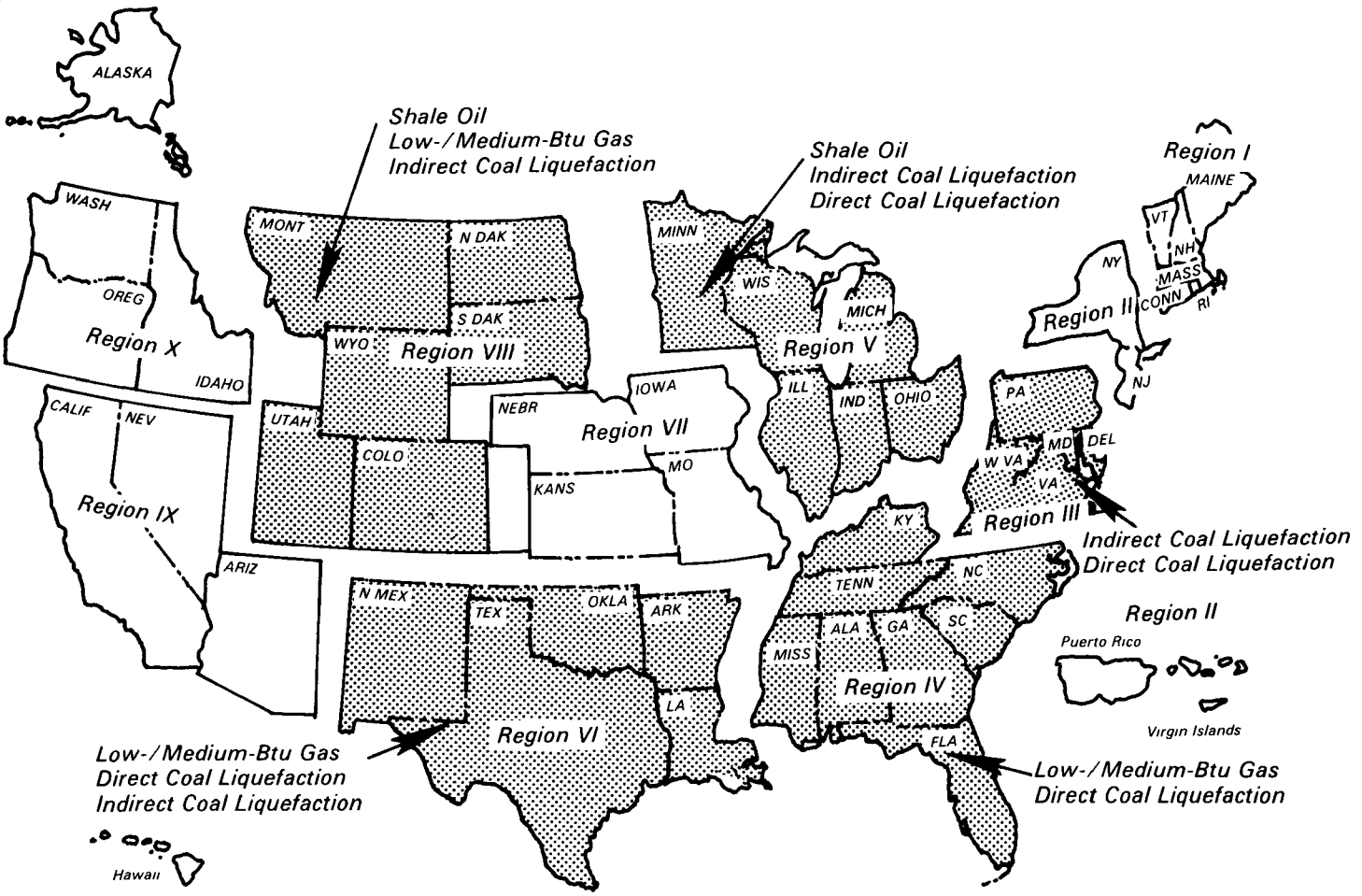

Figure 2. *EPA Regions of synfuel products utilization (1990's).*

the table, the relative ranking considers potential for exposure, emission, toxic hazard, cost of control, and adequacy of existing regulations. A(+) ranking is assigned to a product for an environmental attribute if the product is judged to present greater environmental concern than the petroleum analog; a ranking of (0) indicates that the environmental concern would be similar to or less than that of the petroleum product.

Product Ranking

Table 5 presents the results of synfuel product ranking. The results generally indicate the greatest level of environmental concern and regulatory requirements for shale oil refinery feed and coal liquids. These liquids have been demonstrated to be more hazardous than petroleum crude and fuels oils (a major factor in assigning a "1" ranking). This and the fact that shale oil products will be the synfuels that are expected to first enter the market on a large scale, are the major factors that flag near-term environmental concerns for shale oil products in general and shale oil fuel and refinery feed in particular.

Data Limitations and Related Programs

As noted previously, a number of major gaps in the existing data base preclude accurate analysis of the environmental concerns associated with a future large-scale utilization of synfuel products in the U.S. These gaps relate to: (1) present uncertainties regarding the size of the industry, specific synfuel technologies that will be used, product slates that will be produced, locations of production facilities and product distribution systems, and the specific areas of synfuel use; and (2) lack of adequate characterization data on synfuel products and on the analogous petroleum products that they will partially or totally replace.

At present, the first category of data gaps can only be partially filled. Many of the gaps in the second category, however, can and should be filled through testing and evaluation of synfuel products obtained from existing U.S. pilot plants and commercial facilities abroad.

Conclusions

- In the next 20 years significant quantities of synfuel products are expected to enter the marketplace and in certain regions a very high percent of the currently used products will be replaced by their synfuel-derived analogs.
- Based on gross characteristics, synfuel products appear to be similar to petroleum products, but detailed characterization data are not available for many of the synfuel and petroleum products with which

Table 3. *Reported Known Differences in Chemical, Combustion, and Health Effects Characteristics of Synfuel Products and Their Petroleum Analogs*

Product	Chemical Characteristics	Combustion Characteristics	Health Effects Characteristics
Shale oil			
Crude	*Higher aromatics, FBN As, Hg, Mn*	*Higher emissions of NO_x, particulate, and (possibly) certain trace elements*	*More mutagenic, tumorigenic, cytotoxic*
Gasoline	*Higher aromatics*	*Slightly higher No_x and smoke emissions*	—
Jet fuels	*Higher aromatics*	*Slightly higher No_x and smoke emissions*	*Eye/skin irritation, skin sensitization same as for petroleum fuel*
DFM	*Higher aromatics*	*Slightly higher NO_x and smoke emissions*	*Eye/skin irritation, skin sensitization same as for petroleum fuel*
Residuals	*Higher aromatics*	—	—
Direct Liquefaction			
Syncrude (H-Coal, SRC II, EDS)	*Higher aromatics and nitrogen*	—	—
SRC II fuel oil	*Higher aromatics and nitrogen*	*Higher NO_x emissions*	*Middle distillates: non-mutagenic; cytotoxicity similar to but toxicity greater than No. 2 diesel fuel; burns skin. Heavy distillate: considerable skin carcinogenicity, cytotoxicity, mutagenicity, and cell transformation*
H-Coal fuel oil	*Higher nitrogen content*	*Higher No_x emissions*	*Severely hydrotreated: non-mutagenic, non-tumorigenic; low cytotoxicity*
EDS fuel oil	—	*Higher No_x emissions*	—
SRC II naphtha	*Higher nitrogen, aromatics*	—	*Non-mutagenic, extremely low tumorigenicity, cytotoxicity, and fetotoxicity*
H-Coal naphtha	*Higher nitrogen, aromatics*	—	*Non-mutagenic*
EDS naphtha	*Higher nitrogen, aromatics*	—	—
SRC II gasoline	*Higher aromatics*	—	—
H-Coal gasoline	*Higher aromatics*	—	—
EDS gasoline	*Higher aromatics*	—	—
Indirect Liquefaction			
FT gasoline	*Lower aromatics; N and S nil*	—	*Non-carcinogenic*
FT by-product chemical	—	*N/A*	—
Mobile-M gasoline	*(Gross characteristics similar to petroleum gasoline)*	—	—
Methanol	—	*Higher aldehyde emissions*	*Affects optic nerve*
Gasification			
SNG	*Traces of metal carbonyls and higher CO*	—	—
Low/medium-Btu gas	*(Composition varies with coal type and gasifier design/ operation)*	*(Emissions of a wide range of trace and minor elements and heterocyclic organics)*	*Non-mutagenic, moderately cytotoxic*
Gasifier tars, oils phenols	*(Composition varies with coal and gasifier types; highly aromatic materials)*	—	—

to assess and compare their safety.

- Large-scale transportation, distribution, and end use of certain synfuel products (for example, heavy distillates derived from coal liquids and shale oil) can present significant threats to the environment and the public health.
- Essentially all synfuel-related environmental projects that are planned or currently underway relate to the design and operation of synfuel plants and not to the subsequent distribution and utilization of products. The present study constitutes the first attempt to focus attention on the potentially broad and far-reaching environmental implications of large-scale marketing and utilization of synfuel products.
- A number of major test and evaluation programs are planned or currently underway to assess the combustion characteristics and general performance of synfuels relative to those of petroleum products. These programs provide excellent opportunities for collecting the environmental data needed for assessing the relative safety of synfuel products, determining the adequacy of the existing control technologies, and identifying regulatory needs.

Recommendations

Based on the results and conclusions of the study, the following recommendations are offered:

Table 4. *Relative Assessment of the Environmental Hazards Associated with Synfuel Products and Petroleum Analogs*

Product	Exposure		Emission Factor		Toxic Hazard			Adequacy of Existing Regulations			
	Transport & Storage	End Use	Transport & Storage	End Use	Transport & Storage	End Use	Cost of Control	CAA	CWA	RCRA	TSCA
Crude shale oil (fuel)	+	0	0	+	+	+	+	+	+	+	0
Shale oil refinery feed	+	0	0	0	+	+	0	0	+	+	0
Shale jet fuel	0	0	0	+	0	+	+	+	0	+	0
Shale diesel fuel	0	0	0	+	0	+	+	+	0	+	0
Shale residuals	0	0	0	+	+	+	+	+	+	+	0
Shale gasoline	0	0	0	+	0	+	+	+	0	+	0
Low-/Medium-Btu gas (coal)	0	0	0	+	+	+	+	+	0	+	0
SNG (coal)	0	0	0	0	0	0	0	0	0	0	0
Gasifier tars and oil	0	0	0	+	+	+	+	+	+	+	0
Gasifier phenol	0	0	0	+	+	+	0	0	0	0	0
F-T LPG	0	0	0	0	0	0	0	0	0	0	0
F-T medium-Btu gas	0	0	0	0	0	0	0	0	0	0	0
F-T SNG	0	0	0	0	0	0	0	0	0	0	0
F-T heavy fuel oil	0	0	0	0	0	0	+	0	0	+	0
F-T gasoline	0	0	0	0	0	0	0	0	0	+	0
M-gasoline	0	0	0	0	0	0	0	0	0	+	0
F-T diesel fuel	0	0	0	0	0	0	0	0	0	+	0
Fuel methanol		0	0	+	0	0	0	+	0	+	0
SRC II fuel oil	+	0	0	+	+	+	+	+	+	+	0
SRC II naphtha	0	0	0	0	+	+	0	0	+	+	0
SRC II LPG	0	0	0	0	0	0	0	0	0	0	0
EDS fuel oil	+	0	0	+	+	+	+	+	+	+	0
EDS naphtha	0	0	0	0	+	+	0	0	+	+	0
EDS LPG	0	0	0	0	0	0	0	0	0	0	0
H-coal fuel oil	+	0	0	+	+	+	+	+	+	+	0
H-coal naphtha	0	0	0	0	+	+	0	0	+	+	0
H-coal LPG	0	0	0	0	0	0	0	0	0	0	0

- *More systematic approach to product characterization and testing.* Better coordination among various on-going and planned studies (perhaps through establishing a "test tracking" system that would promote exchanges of information among various studies) is recommended to avoid duplication of effort and to ensure generation of appropriate environmental data in a most cost-effective manner.
- *Collection of environmental data in conjunction with planned performance testing programs.* Collection of environmental data, which can be correlated with performance, which can be correlated in conjunction with product performance, in conjunction with a systematic product characterization effort can provide valuable timely inputs to the evolution of the synfuel industry and would ensure that: (1) environmental considerations are included in the selection of processes, equipment, and product slates for commercial facilities; and (2) the drafting of specifications for synfuel products, new source performance standards for synfuel plants, and emissions standards for facilities using synfuel products is based on the best available technical and engineering data.
- *Consideration of end-use environmental implications in the selection of the product slates and in the development of the synfuel industry.* By proper selection of the refining steps (and the operating mode for some synfuel processes), the product slate can be altered to favor the production of those products that present fewer and more controllable end-use environmental impacts. Studies should be undertaken to define the engineering and economics of selecting environmentally acceptable product slate possibilities for various synfuel technologies.
- *Compilation of characterization/performance data on analogous petroleum products.* Very little data are available on potential pollutants and toxicological and ecological properites of many of the petroleum products to provide a baseline for assessing the safety of synfuel products. It is recommended that the potential sources of data on petroleum products be contacted in an effort to compile all available data and identify data gaps. Also, synfuel product testing and characterization efforts should include parallel testing of petroleum-derived analogs.

Table 5. *Priority Ranking of Synfuel Products from the Standpoint of Environmental Concerns**

Product	1980-1987	1988-1992	1993-2000
Crude shale oil (fuel)	2	—	—
Shale oil refinery feed	1	1	1
Shale jet fuel	2	2	2
Shale diesel fuel	2	2	2
Shale residuals	2	2	2
Shale gasoline	2	2	2
Medium-Btu gas (coal)	2	2	1
SNG (coal)	3	3	3
Gasifier tars & oils	—	1	1
Gasifier phenol	2	2	2
F-T LPG	—	3	3
F-T medium-Btu gas	—	3	3
F-T SNG	—	3	3
F-T heavy fuel oil	—	3	3
F-T gasoline	—	3	3
Mobile-M gasoline	—	3	3
F-T diesel fuel	—	3	3
Fuel methanol	—	1	1
SRC II fuel oil	—	1	1
SRC II naphtha	—	2	2
SRC II LPG	—	3	2
EDS fuel oil	—	—	1
EDS naphtha	—	—	2
EDS LPG	—	—	3
H-coal fuel oil	—	—	1
H-coal naphtha	—	—	2
H-coal LPG	—	—	3

*Degree of concern: most = 1, modest = 2, and low = 3; — indicates product not produced or not used as indicated

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The complete report, entitled "Environmental Aspects of Synfuel Utilization," (Order No. PB 81-175 937; Cost: $29.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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