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# ASSESSMENT OF TRACE CONTAMINANTS FROM A MODEL INDIRECT LIQUEFACTION FACILITY. VOLUME I. SUMMARY AND CONCLUSIONS

GENERAL RESEARCH CORP. MCLEAN, VA

**JAN 1982** 



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# ssessment of Trace

# **Contaminants From a Model**

# **Indirect Liquefaction Facility**

#### VOLUME I - SUMMARY AND CONCLUSIONS

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January 1982

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## **Prepared For:**

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#### FOREWORD

Development and deployment of a commercial indirect liquefaction industry has been proposed as a means of reducing United States dependence on foreign sources of energy.

Deployment of a commercial industry on an environmentally acceptable basis requires identification and evaluation of potential environmental problems. This assessment is an attempt to anticipate potential environmental hazards that may be posed by commercial-scale facilities to provide an improved basis for planning and implementing environmental research.

The study comprises four major tasks: characterization of hazardous materials released from an indirect liquefaction facility; assessment of ecological hazards; assessment of public health hazards; and assessment of occupational health hazards. The report is organized in the same manner. Volume I is an overview and summary of the results; volume II presents stream characterization data; and volumes III, IV and V present assessments of ecological, public health and occupational health hazards, respectively.

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#### EXECUTIVE SUMMARY

Indirect liquefaction of coal is a promising technology for producing synfuels. Recent studies indicate that if any portion of the national synfuels goals for 1987 and 1992 is to be met with coal liquefaction, the bulk of the production is likely to come from indirect processes. The emphasis that the Synthetic Fuels Corporation is placing on technologies that are available for deployment on a commercial-scale may provide further impetus for indirect processes, several of which are in operation or being designed on a commercial scale in foreign countries.

An indirect coal liquefaction industry will benefit the nation by providing a critically needed supplement to our dwindling oil and gas reserves. However development and deployment of a commercial coal indirect liquefaction industry is not without risks. To ensure development and deployment of indirect processes in an environmentally acceptable manner, potential hazards to the general public, occupational personnel and ecosystems must be assessed and factored into the design, siting and operation of commercial facilities. At present the potential adverse environmental impacts of indirect liquefaction facilities are not well understood. Especially lacking is information on the identity and quantity of trace contaminants that may be released from process and waste streams.

The purpose of this assessment is to anticipate and define the potential hazards posed by trace pollutants emanating from the indirect liquefaction of coal. This will provide a basis for planning and performing environmental research necessary to mitigate or eliminate future environmental problems, thereby allowing deployment of a commercial indirect liquefaction industry on a timely and environmentally acceptable basis. The results of this assessment, if integrated with information on control technologies and existing or on-going environmental assessments of criteria pollutants (such as particulates and nitrogen oxides, 'etc.), should provide the type of information required for the performance of a risk assessment associated with the deployment of specific indirect liquefaction processes. In addition, the results of this study should be of general use to investigators and decision makers interested in the evaluation of control technology options and siting of indirect liquefaction facilities.

The assessment methodology is illustrated in Figure S-1. Selection of a specific process is the starting point of the assessment. Indirect liquefaction of coal is essentially a two-phase operation: gasification of coal to produce synthesis gas, followed by catalytic synthesis of liquid products from the synthesis gas. Several process options exist for each phase. Lurgi dry ash gasification and Fischer-Tropsch synthesis have been selected to represent the gasification and catalytic synthesis phases, respectively. These processes have been selected because they are proven on a commercial scale; and technical and environmental data from the processes, although limited, are more readily available and more representative of commercial-scale operations than are data from other processes.

A hypothetical commercial-scale Lurgi/Fischer-Tropsch plant has been designed to provide the basis for estimating the types and quantities of pollutants that might be released from a commercial facility. The model plant includes production facilities, support facilities and environmental controls. Facility streams include products, by-products, internal process streams, gaseous emissions, aqueous effluents, solid wastes and leachates. A simplified block flow diagram of the plant is presented in Figure S-2.

A wide variety of controls have been proposed for use in coal conversion facilities. The environmental controls specified in the hypothetical plant, have been selected as representative of the types of controls that have been proposed. The wastewater treatment systems proposed for the hypothetical plant have been designed to achieve zero

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Figure S-1 Overview of Assessment Methodology

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discharge and recover contaminants as by-products wherever economically These systems include tar/oil separation, phenol recovery, feasible. ammonia stripping and recovery, biological Greatment, and reverse osmosis. A variety of control processes have been selected to control atmospheric emissions, including bag houses, lime slurry scrubber, electrostatic precipitator (ESP), venturi scrubbers, sulfur recovery, incineration, and special vessels for storing products and by-products. Solid waste streams from the model facility are assumed to be disposed of in the mine. Spent catalysts" are assumed to be reclaimed.

A mass balance for the facility has been developed. Mass flows of major stream components are based largely, though not exclusively, upon information in a report prepared by the Mobil Research and Development Corporation, Research Guidance Studies to Assess Gasoline from Coal by Methanol-to-Gasoline and SASOL-type/fischer-Tropsch Technologies. Estimates of mass flows of minor scream components are based on a variety of data sources and engineering judgements, and generally have been used to identify hazardous streams that require further characterization.

Selection of streams for the assessment is based on consideration of three factors: 1) stream flow rate, 2) probability of release to the environment, and 3) presence of hazardous components.

Hazardous components considered in the assessment, include:

- ammonia
- aromatic amines
- substituted benzenes
- carbon monoxide
- carbonyl sulfide
- hydrogen cyanide
- mercaptans
- nitrogen<sup>i</sup> heterocyclics
- nitrogen oxides
- hydrogen cyanide
- nickel.carbonyl

- oils
- oxygen heterocyclics
- phenols
- polynuclear aromatics
- sulfur heterocyclics
- sulfur oxides
- tars
- trace elements
- aliphatic, alicyclic  $\odot$   $\simeq$ and carboxylic hydrocarbons nitrosamines

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Review of the literature indicates that chemical characterization data for releases from commercial-scale Lurgi/Fischer-Tropsch plants are very limited. Chemical characterization of streams has been accomplished using experimental data from the literature, whenever possible. For those environmental releases for which little or no data were available, pollutant concentrations have been estimated by characterizing precursor streams and then estimating the quantity of each pollutant that would remain in streams after treatment. Stream characterization is limited to those streams that would be released under normal operating conditions. Releases during upset conditions and accidents have not been considered due to the lack of data.

Characterization of the types, concentrations and quantities of chemical components in streams released to the environment provides the basis for estimating the resultant exposure concentrations. Because of the relative scarcity of pollutant data, and the lack of information on site-specific characteristics. sophisticated environmental modeling has not been used to evaluate pollutant dispersion. In may cases, estimation of post-dilution pollutant concentrations are based upon the use of either the U.S. Environmental Protection Agency's Source Analysis Model (SAM/I), or other very simple environmental dilution models.

The hazards posed by each pollutant are then assessed in relation to three groups of potential receptor populations (i.e., general public, occupational personnel, and ecosystems) by comparing the projected postdilution, pollutant concentration with quantitative benchmarks, such as biological thresholds or recommended acceptable pollutant levels, and average ambient air or water concentrations.

Benchmarks used in assessing ecosystem hazards include:

- Proposed Freshwater Criteria,
- Estimated Permissible Concentrations.
- Lowest Observed Toxic Concentrations,
- Lowest Observed Lethal Concentrations
- Mean Toxic Concentrations,
- Daphnia Chronic Toxic Concentrations,
- Threshold Bioaccumulation Concentrations

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- Ambient Freshwater Concentrations,
- Most Stringent Criteria,

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Ambient Air Concentrations.

Benchmarks used in assessing hazards to public health include:

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- Estimated Permissible<sup>†</sup> Concentrations,
- National Ambient Air Quality Standards,

Drinking Water Standards.

Relative hazards posed by each pollutant to each receptor are categorized based on the ratio of the estimated post-dilution concentration to toxicologic benchmarks. Compounds with a post-dilution concentration to benchmark ratio greater than 10 are classified as "Probable Hazards." Those with a ratio of 10 or less, but greater than or equal to 0.1, are classified as "Possible Hazards". Those with a ratio less than 0.1 are classified as "Unlikely Hazards".

Assessment of occupational health hazards requires evaluation of the toxicity of potential stream constituents and the exposure of occupational personnel to these toxic constituents. Unlike the assessments of public health hazards and ecosystem hazards, which emphasize facility waste streams released to the environment, the assessment of occupational health risks focuses on internal process streams that could release toxic substances due to leaks, fugitive emissions, spills and other non-routine events. Problematic stream constituents are identified by using an indicator compound concept and composite hazard index methodology. In this approach, the concentrations of gaseous components in process streams that may leak into the occupational environment are compared with their appropriate threshold limit values (TLVs). The process stream concentration to TLV ratio has been computed for each constituent and then compared with a similarly derived ratio for carbon monoxide, which was selected as the indicator compound for the assessment. These ratios then are used to calculate the allowable leak rate for each stream component relative to the allowable leak rate for carbon monoxide, assuming that carbon monoxide would be monitored carefully in the occupational setting. Hazards to the occupational population then are categorized based upon the value of the relative allowable leak rate, Compounds with a relative allowable leak rate less than 0.1 are classified as "Probable Hazards". Those with a relative allowable leak

rate greater than 0.1 but less than 1.0 are classified as "Possible Hazards". Finally, those with a relative allowable leak rate greater than 1.0 are classified as "Unlikely Hazards".

Based upon the use of carbon monoxide as an indicator compound within the workroom environment, the results of the occupational health assessment indicate that tars and oils from the gasifier are the only Probable Hazards to workers. Carbon dioxide and methane represent Possible Hazards from one or more process streams. Emissions of nickel carbonyl and hydrogen sulfide also may pose some concern.

Projected hazards to the general public and ecosystems posed by components of six selected facility streams are summarized in Tables S-1 and S-2. Evaluation of the results indicates that hazards vary by receptor group, stream and chemical class of constituents.

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Stack gas produced as a result of utilities generation is the largest planned environmental release from the hypothetical facility, with a flow rate of approximately 7.1 million pounds per hour. Comparison of estimated post-dilution concentrations of sulfur oxides, nitrogen oxides and trace elements with public health and ecological benchmarks indicates that none of the stream constituents pose a Probable Hazard, but each represents a Possible Hazard to public health and ecosystems.

Cooling tower atmospheric losses for the hypothetical plant are projected to be 2.4 million pounds per hour. Although many industries have cooling towers, the emissions from the hypothetical plant are unique because treated process wastewater is used in the cooling system tower. Comparison of the estimated post-dilution concentrations with health benchmarks results in the classification of arsenic and ammonia as Possible Hazards to public health. The cooling tower losses appear to pose the greatest short-term atmospheric threat to local terrestrial ecosystems due to the large quantities of organics and trace elements released, but quantitative estimates have not been made due to lack of data regarding pollutant partitioning among drift, evaporation, and blowdown.

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ABLE S-1 : <sup>)</sup>HAZARD POTENTIAL OF AQUEOUS STREAM CONSTITUENTS\* (Streams 53,69 and 70). ----

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. • • N LY ۲ ٠ Constituent identified in Stream but benchmark not available 28 EPC • ٠ • ۲ • • 27 PFC 0 • ٠ 0 23 24 25 26 LOTC HTC DCTC TBC o • . • Fcological 0 • 0 ł 0 STREAH 70 - BLOSLUDCE 0 C 0 ⊚ 0 . 0 . 0 e ż 22 • 0 ۲ 0 • Public Health 20 21 AFC. 00 00 • 0 0 0 0 ۲ o **B** 7 0 0 0 ; 0 0 , 13 14 15 16 17 EPC 1.01C MTC NCTC TBC 00 00 00 0 00 0 0 00 0 STREAM 69 - ASH LEACHATE 00 0 0 0 0 0 o i Ecological 00 00 0 0 0 0 0 0 0 i 00 clo oló 0 0 0 0 0 00 0, 00 00 0 0 0 00 Public Henith -11 12 EPC UNS 0 ۲ ۲ 0 0 0 . ⊚ 1 1 Ö ı ۲ t AFC • ۲ . • 0 00 • . Θ 2 4 9 PFC ۲ . • • ø ſ STREAH 53 - REVERSE OSHOSIS WASTE 
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blank<sup>°</sup> Constituent not identified

POTENTIAL, MAZARD: (Post-Dilution)/(Benchmark)>0.4 hut <10 PRODABLF HAZARD: (Post-Dilution)/(Benchmark)210

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<u>Column</u>	<u>Abbrev Lat Lon</u>	:	<u>Explaneri on</u>	Column	Abhrevlation	<u>Explanation</u>
	EPC	.•	Estimated Permissible Concentration	16	DCTC	<u> Daphuin</u> Chranic Toxic Concentration
2	DWS	<i>.</i>	Drinking Water Stondard	T7	TBC	Threshold Bioaccumulation Concentration
n	TOLC		Lowest Observed LC <sub>30</sub>	18	PFC	Proposed Freshuater Criteria
4	LOTC	:	Lowest Observed Toxic Concentration	19	AFC	Amblent Freshwater Concentration
'n	EPC .		<b>Estimated Permissible Concentration</b>	20	I	Not Evoluated
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	DCTC .		<u>Daplinia</u> Chronic Toxic Concentration	22	DIOL	$l.$ buegt Observed $l.C_{50}$ .
8	TRC .	÷	Threshold Bloscomulation Concentration	23	LOTC	Lowest Observed Toxic Concontration
5	PFC		Proposed Freshwater Criteria	24	NTC	Mean Toxic Concentration
10	AFC		, Amhlent Freshvater Concentration	25	. bctc	<u>Daphnia</u> Chronic Toxic Concentration
11	Dda		Estimated Permissible Concentration	26	TBC	Threshold Bloaccomulation Concentration
12	SHO		Drinking Water Standard	27	PFC	Proposed Freshwater Criteria
13"	DAE		Estimated Permissible Concentration	28	EPC	Estimnted Permissible Concentration
14	LOTC		Lovest Observed Toxic Concentration	29	AFC	Amblent Freshwater Concentration
15	MTC		Hean Toxic Concentration			

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TABLE S-2: HAZARD POTENTIAL OF ATMOSPHERIC STREAM CONSTITUENTS \* (Streams 28,29 and 72).

Constituent identified in Stream but benchmark not available ۱<u>،</u> ... EPCAE Ecological STHEAH 72 LOCKIGITER VENT GAS Public 1 1 14.5 0 0 2 ¥ ļ, 12 NAAQS lleal th /; /© ····· EPC AII ◉ blank Constituent not identified li (ر <sup>نبو</sup>ر) : Ecological 2 F. -:-STREAM 29 CODLING TOWER ATMOSFILERIC LOSSES Fublic Realth Realth **HAVITIVAS** BRAGS .. 0 . © 0 ETCAI 00 1 0 0 00 0 0 10 0 0 0 1 0 9YC • :: : 00 ۲ • •• UNLIKELY HAZARD: (Post-Dilucion)/(Benchmark) 50.1 \* FOTENTIAL HAZARD: (Post-Dilution)/(Benchmark)>051.but<10 EPCALLE 0 0 • • • 5 Ecological STREAH '28 - UTILITY STACK CAS .: 4 LOTC 0 0 10 1 n K 00 0 0 0 ا الرا haags Í 0 t ı Public licalth ..... <sup>(</sup>';<u>;</u>, '... 00 ٩. EPCAH 0 0 • 1,2 4-Trimethylhenzene 3-Hethylbutanole Acld **2-Hethylbutanoic Acid** TOTAL TRACE ELEMENTS BENZENES & SUBSTITUTED ALIMATICS, ALICYCLICS TOTAL FATTY ACIDS **Fentanolc Acid Propanolc Acid** Hexanoic Acid Butanole Acid Ethylbenzene RACE ELEMENTS Acetic Acid Nickel D Hanganese Beryllium o-Xylene Selentum Aluminum Vanadium Fluorine Biphenyl Cadmitum Lead . Hercury Toluene Argenic Copper Boran Indan `© Iron 21nc 0

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Column headings defined on final page O UNLIKELY HAZARD: {Post-Dilution)/(Denchmark) ≤ 0.1
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 DISORABLE HAZARD: {Post-Dilution)/(Denchmark) > 10
 PROBABLE HAZARD: {Post-Dilution)/(Denchmark) ≥ 10
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TABLE S-2 (Concluded)

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Estimated Permissible Concentration in Air for Protection of Numan Health Estimated Permissible Concentration in Air for Protection of Human Health, or Ecology Estimated Permissible Concentration in Air for Protection of Human Health Estimated Permissible Concentration in Air Estimated Permissible Concentration in Air National Ambient Air Quality Standard National Ambient Air Quality Standard National Ambient Air Quality Standard Lowest Observed Toxic Concentration for Protection of Human Health Ambient Air Concentration for Protection of Ecology Most Stringent Criteria Explanation Toxic Concentration Not Evaluated Not Evaluated ۰, Abbreviation EPC<sub>AH</sub>, E EPC<sub>AH</sub> EPC<sub>AH</sub> . EPCAE Ļ NAAQS NAAQS NAAQS EPCAH LOTC AAC MSC JC .... • 3 Ċolumn N 14 2 12 5 11

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Comparison of estimated post-dilution concentrations with ecological and public health benchmarks indicates that none of the components in coal lockhopper vent gas pose a Probable Hazard to either public health or ecosystems. Ammonia, hydrogen sulfide and nickel carbonyl are classified as Possible Hazards to public health.

Concentrated waste from the reverse osmosis unit is the largest aqueous waste stream requiring ultimate disposal. Although precursor wastewater streams are treated rather intensively (i.e., tar/oil separation, phenol recovery, ammonia recovery and biological treatment) prior to concentration of pollutants in the reverse osmosis unit, the quality of the concentrated waste stream is such that inadvertent release into groundwater (through leaching) or surface water (through leaks), as assumed in this study, may pose hazards to human health and ecosystems. Comparison of estimated post-dilution pollutant concentrations with ecological and public health benchmarks indicates the eleven classes of compounds (trace elements and ten classes of organics) may pose a Probable to Possible Hazard to humans and ecosystems. Based on results of the screening process, six trace elements (As, Be, Cd, Hg, Mn, and Ni) are classified as Probable Hazards. The other four trace elements for which post-dilution concentration have been estimated (Pb, B, F, and V) are categorized as Possible Hazards to ecosystems and Three classes of organics (phenols, polynuclear public health. aromatics and mercaptans) are categorized as Probable Hazards and two classes (carboxylic acids and substituted benzenes) are estimated to pose Possible Hazards. Five additional classes of organics (aromatic amines; nitrosamines; and sulfur, nitrogen and oxygen heterocyclics) are classified as Possible Hazards because the lack of information or 'toxicological benchmarks results in a very large degree of uncertainty.

Leachate from ash and sludge disposal is not a planned environmental release, but may occur if disposal is in the mine, as assumed in the hypothetical plant. Results of the hazard screening process, indicate that none of the trace elements pose a Probable Hazard to either public health or ecosystems. Six elements (Al, Cd, Fe, Pb, Mn, and Se) are classified as Possible Hazards.

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No data are available regarding the composition of sludge generated by biological treatment of Lurgi/Fischer-Tropsch wastewater, or the composition and quantity of biosludge leachate. Toxic materials in biosludge have been estimated by assuming that removal of trace elements and the polynuclear aromatic hydrocarbons is via adsorption and sedimentation with the biosludge. The toxic contaminants are assumed to leak into a small (10 cfs) stream. Comparison of estimated postdilution concentrations with toxicologic benchmarks indicates that trace metals and polynuclear aromatic hydrocarbons may pose a Probable Hazard to ecosystems. The hazard to public health was not assessed.

Tables S-1 and S-2 present the hazard to ecosystems and public health by specific compounds in individual streams for which postdilution pollutant concentrations have been estimated. The overall hazard posed by each class of pollutants, however, depends on the total environmental loading due to all streams released to the environment. Because concentrations of pollutants cannot be estimated for many streams, the overall hazard has been assessed only qualitatively. The probability that process and waste streams may release potentially hazardous substances into the environment has been estimated for many of the unquantified streams. Table S-3 summarizes information for all streams that have been quantitatively characterized and identifies all other streams that have been determined to have a high or medium probability of release.

Finally, the information presented in Table S-3 has been modified slightly to account for the degree of uncertainty associated with certain estimates of total environmental loadings. toxicologic technology benchmarks. control options, and biodegradation. Consideration of these factors has resulted in the reclassification of some hazard categories for specific pollutants (i.e., some Unlikely Hazards have been reclassified as Possible Hazards and vice versa). Table S-4 lists the final hazard categories for the classes of compounds addressed in this assessment.

TABLE S-3

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# SUMMARY OF HAZARDS POSED BY COMPOUND CLASSES IN QUANTIFIED AND UNQUANTIFIED STREAMS

		1 8	IH		VZMI	GASEOUS STREA RD LEVEL IN	SH		"	L SI	ATE	Ĩ	IQUID AND SOLID (REVEALED )	TREMIS :
QUANTIFIE	QUANTIFIE	<b>QUANTIFIE</b>	NTIFIE	<b>H</b> 1		STREAMS*				라	Ē		STREAMS*	
ECOLOGICAL IEALIC 20 29 72 28 29	00 ICAL FUBLIC	2 28 29	FUBLIC IEALT	35-		2 DECUPATIONAL	PRESENCE IN UNQUANTIFIED STREAMS*	53 53	0010	코지	김별대		7] OCCUPATIONAL	PRESENCE IN UNQUANTIFIED STREAMS*
4 0 0 4 0	4 9 0	9 9	9	<u> </u>		0	11-7,24-26 M-11,16 L-1,2,0-10,12-15	•	۲	•	•	Ð	•	II-3,27,33,79 H-17,37-40,43,46 L-32,34,44,54
d 0 - 0 d -	P 0 - 0 P	4 0 -	• 0	<u>₽</u>		0	II-7,73,74 M-11,55 L-0,9,10,12	۲	,	1	•		,	11-52 M-17,39-43,46,48,57-59 L-50,54
- 0 4 -	d	-	- 0 -	-			11-7,75	Θ	;	1	•	7	•	•
1 0 1 1 1 1 1 1	1 0 1	-	•	•		0	IL-7,75,76,77 M-11 L-8-10,12	۲	1	1	۲	1	1	H- M-17,39-43,46-48,58,59 L-
- 0 - 0	- 0 - 0 -	· · · ·	•	•		o	II-7,75,76 M-11,55 L-0-10,12-15	•	1	•	0	1	•	II-27,52,70 H-17,22,23,39-43,46-48, 57-59
- d - 0 d -	- d - 0 d	- d - 0	۱ هـ	1		o	II-7,75 H-11,16,55 L-8-10,12-15		1	•	•	•	,	H-39-43,46-40,57
1 0	- 0 4	- 0 -	- 0	1		0	. 1-1	0	• •	1	0		1	II-52 M-39-43,46-48
1 1 1 1 1	1 1 1	1 1	•	•		0	11-7,76	1	1	•	1	•	•	N-52 N-39-43,46-48
- 0 - 0 d -	- 0 - 0 d	- 0 - 0	- 0	-		o <sup>.;</sup>	11-7 11-16,55 12-0-10,12-15	•	•		•	۰.	1	II-52 N-39-43,46-48,57-59 L-44,45,50
- 0 - 0 4 -	- 0 - 0 4	- 0 - 0		-		o	II-7 M-11,55 L-8-10,12-15	0	,	·	0	-	•	11-27,52 M-39-43,46-48,57-59 L-44,45,50,54
- d' 0 d	- d' 0 d	- d' (	- d	1		0	II-7 M-11,55 L-8-10,12-15	, : 	•1	1	•	•	- 13	H-27,52 H-39-43,46-48,57-59 L-44,45,50,54
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0	0 -	0	0	0	0	ii	l -7   -1 ,55  L-8-10,12-15,56	۲	1	,	1	1	•	II-63
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TABLE S-3 (concluded)

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	GASEOUS STREMIS	ID LEVEL IN ESTIMATED INZARD LEVEL IN STREAMS*	OCCUPATIONAL PRESENCE IN ECOLOGICAL REALTIN OCCUPATIONAL PRESENCE IN	Z HEALTH UNQUARITYTED STREAKS* 53 69 71 53 69 71 HEALTH UNQUARTEFTED STREAKS*	0     11-7     -     -     -     -     -       H-11,65     L-0.10,12-15     L-0.10,12-15     L-0.10,12-15     L-0.10,12-15	0     II-7,51     - <t< th=""><th>0     II-7     -     -     -     -     -       II-11, 16, 10, 55     -     -     -     -     -       L-9-10, 12-15, 56     -     -     -     -     -</th><th></th><th></th><th>II-7.76     I-     I-     I-       H-11     I-     I-     I-       L-8-10,12     I-     I-</th><th>H-11</th></t<>	0     II-7     -     -     -     -     -       II-11, 16, 10, 55     -     -     -     -     -       L-9-10, 12-15, 56     -     -     -     -     -			II-7.76     I-     I-     I-       H-11     I-     I-     I-       L-8-10,12     I-     I-	H-11
	GASEOUS STREAMS	LEVEL IN Eams*	OCCUPATIONAL	NEALTH UN	0	0	0		c	•	÷±. ●
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1		ED AV	PUBL	52	•			•	1	'	1
		TAT		2		<b></b>	<u>-</u>	•	9		<u> </u>
	ŵ	ESI	KI CA	2	0	0	0		-	Ľ'	<u>،</u>
			COL C	2	<u>'</u>	•	· ·		•	<u> </u>	·
				ন ।	- <u>'</u>	• 	<b></b>	0	•	<u> </u>	<u>'</u>
			, CLASSES OF	COMPOUNDS	ILYDROGEN CYANIDE	NYDROGEN SULFIDE	HICKEL CARBONYL	NITROGEN OXIDES	SULFUR OXIDES	TARS	0115

key:

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H-High, H-Medium, L-Low, refer to probability of stream release to environment.

Probable llazard
Possible llazard
Uhilkely llazard
Uhilkely llazard
Unilkely llazard
Class present, hazard level not estabilished
Class presence unknown, hazard level not estimated

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# TABLE S-4

# FINAL ANALYSIS OF HAZARD CATEGORIES FOR CHEMICAL CLASSES RELEASED FROM THE MODEL LURGI/FISCHER-TROPSCH FACILITY

PROBABLE HAZARDS	POSSIBLE HAZARDS	UNLIKELY HAZARDS
Trace Metals	Aliphatics, alicyclics,	Ammonia*
	and fatty acids	
Polynuclear Aromatic		Carbonyl Sulfide
Hydrocarbons	Benzenes, and Substituted	
	Benzenes	Hydrogen Cyanide
Mercaptans		10 C
	Phenols	Carbon Dioxide
Tars and Oils		· ·
	Sulfur. Nitrogen and	
	Orven Heterocyclics*	
	ongen maastoojerred	
	Aromatic Amines*	
	Nitrosamines* .	
	Hydrogen Sulfide	
	Nickel Carbonyl	
ų.	Sulfur and Nitrogen Oxides	

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\*These chemical classes have had their hazard level either upgraded or downgraded from that identified in Table S-3 based upon consideration of these additional factors: the degree of uncertainty associated with estimates of environmental loading, toxicologic benchmarks, control technology options, and biodegradation.

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In summary, 79 process and waste streams from a model Lurgi-Fischer-Tropsch facility have been identified for initial evaluation. Of these, nine gaseous emissions streams, ten aqueous and solid waste streams, and numerous internal process streams have been characterized in more detail. Based upon the assumptions and limitations of the present study, trace metals, polynuclear aromatic hydrocarbons, mercaptans, tars and oils have been classified as Probable Hazards to one or more receptor groups (i.e., occuptional personnel, general public, and/or ecosystems). In addition to these constituents, aliphatics, alicyclics and fatty acids; substituted benzenes; phenols; aromatic amines; nitrosamines; hydrogen sulfide; nickel carbonyl; and nitrogen oxides and sulfur oxides are classified as Possible Hazards.

Probable Hazards were identified in the reverse osmosis waste stream, leachate from biosludge, and internal gasifier streams. Possible Hazards were associated with these and other streams, including coal lockhopper vent gas, stack gas from utilities, evaporative losses from utilities generation, leachate from ash/scrubber sludge, and several internal process streams.

It is extremely difficult to assess the hazard potential associated with trace contaminants from a preoperational facility. A number of factors that may affect the type, magnitude and severity of hazards posed by a future facility cannot be determined at this time; therefore, a great deal of uncertainty must be associated with the results of this However, the present study represents a comprehensive assessment. summary of the available information concerning the identity of both organic and inorganic trace contaminants associated with the lurgi/ Fischer-Tropsch technology. Some basic assumptions, cautious extrapolations, and simple diffusion models have been applied to this information to estimate the potential exposure concentrations of potentially hazardous chemicals and chemical classes to workers, the general public, and both aquatic and terrestial ecosystems. The information presented provides a source of data which should assist environmental research and development planning activities, the evaluation of control technology options, the siting of facilities, and the development of a more detailed assessment of risks from indirect liquefaction processes.

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## 1 INTRODUCTION

#### 1.1 BACKGROUND AND PURPOSE

Indirect liquefaction processes are leading technological candidates for the production of synthetic fuels from coal. A recent Government Accounting Office report concluded that if any portion of the national synfuels production goals for 1987 and 1992 is to be met with coal liquefaction, the bulk of the production is likely to come from indirect processes.<sup>199</sup> And the Synthetic Fuel Corporation's emphasis on established technologies ready for deployment on a commercial scale may provide an additional impetus to indirect processes, several of which are operating or under development on a commercial scale in foreign countries.

An indirect coal liquefaction industry will benefit the nation by providing a critically needed supplement to our dwindling oil and gas reserves. The synthetic oil and gas produced will be environmentally compatible and clean burning, the products will be both storable and transportable, and synthetic oil and gas will make us less dependent on unstable and costly foreign supplies.

However development and deployment of a commercial indirect coal liquefaction industry is not without risks. To ensure that technology development and deployment proceeds in a timely and eventually acceptable manner, potential hazards to the general public, occupational personnel and ecosystems must be assessed and considered in the design, siting and operation of commercial facilities.

At present the potential adverse environmental impacts of an indirect liquefaction industry or facility are not well understood. A number of recent studies have attempted to assess the hazards associated with coal liquefaction. However, the assessments generally have been limited to major pollutant species (e.g., sulfur oxides, nitrogen oxides, and total suspended solids). Although trace elements and trace organics have been identified as potentially significant problems, efforts to estimate the environmental and health hazards associated with
their release from indirect commercial liquefaction facilities have been limited due to lack of data. The purpose of this assessment is to anticipate and define the potential hazards posed by trace pollutants to provide a basis for planning and accomplishing environmental research necessary to mitigate or eliminate future environmental problems and allow deployment of a commercial indirect liquefaction industry on a timely and environmentally acceptable basis. This information also should provide a framework from which a more detailed environmental risk assessment could be performed. Furthermore, the results of this study should be of general use to investigators and decision-makers responsible for the evaluation of control technology options and the siting of commercial facilities.

#### 1.2 OVERVIEW

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Lack of adequate, standardized methodologies and a paucity of data make environmental hazard assessment difficult, even for those technologies that have been in existence on a commercial scale for many years. Assessment of hazards associated with technologies such as indirect coal liquefaction, which do not have a long history of operation in the U.S., is even more difficult because an historical data base is not available, and uncertainty regarding market penetration and geographic deployment of a commercial industry makes evaluation of sitespecific factors very difficult.

Selection of a specific process has been the starting point of the assessment. Indirect liquefaction of coal is essentially a twophased operation: gasification of coal to produce synthesis gas, followed by catalytic synthesis of liquid products from the synthesis gas. Several process options exist for each phase. Lurgi dry ash gasification and Fischer-Tropsch synthesis have been selected to p

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Figure 1–1 Overview of Assessment Methodology

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represent the gasification and catalytic synthesis <sup>3</sup> phases, respectively. These processes have been chosen because they have been proven or a commercial scale; and technical and environmental data from these processes, although limited, are more readily available and more representative of commercial-scale operations than are data from other processes.

Determination of the types and quantities of hazardous pollutants that might be released from a commercial-scale Lurgi/Fischer-Tropsch facility is a critical, difficult step in the analysis. It is a critical step because the types of pollutants determine the associated hazards, and the quantities of pollutants determine the resultant post-dilution environmental concentrations and exposure levels due to stream discharges. It is a difficult step because data are very To provide a basis for the identification of hazardous . limited. pollutants, a hypothetical Lurgi/Fischer-Tropsch facility has been The hypothetical plant includes production facilities, designed. support facilities and environmental controls. Facility streams include products, by-products, internal process streams, gaseous emissions, aqueous effluents, solid wastes and leachates. Process operating conditions and a Wyoming subbituminous feed coal have been specified to facilitate pollutant characterization.

Chemical characterization of streams has been accomplished using experimental data from the literature, whenever possible. For those environmental releases for which little or no data are available, pollutant concentrations have been estimated by characterizing precursor streams and then estimating the quantity of each pollutant that would remain in streams after treatment. Stream characterization is limited to streams released under normal operating conditions. Releases during upset conditions and accidents are not considered due to the lack of data.

Characterization of the types, concentrations and quantities of chemical components in streams released to the environment provides the

basis for estimating the resultant environmental exposure concentrations. Because of the relative scarcity of pollutant data, and the lack of information on site-specific characteristics, sophisticated environmental modeling has not been used to evaluate pollutant transport. Instead, dilution factors, based upon either the Source Analysis Model (SAM/I) being developed for the U.S. Environmental Protection Agency or other very simple environmental dilution models, have been applied to the projected environmental releases to estimate environmental concentrations resulting from facility discharges.

The biological effects of each pollutant have been identified in the literature to determine the hazards posed by the pollutants to each potential receptor group. Quantitative benchmarks, such as biological thresholds or recommended acceptable levels, have been used as references for comparison with projected pollutant concentrations. Based upon the ratios of estimated pollutant concentrations to toxicologic benchmarks, the various chemical constituents have been categorized by degree of hazard (i.e., Probable, Possible and Unlikely).

The ecological, public health, and occupational health assessments are based upon a common but flexible approach that has allowed each assessment to differ, depending upon the specific assumptions and available data associated with the different exposure populations.

1.3 ORGANIZATION OF THE REPORT

The assessment comprises four major tasks: 1) characterization of hazardous materials released from an indirect liquefaction facility; 2) assessment of ecological hazards; 3) assessment of public health hazards; and 4) assessment of occupational health hazards. The report is organized in the same manner. This volume is a compilation and integration of results of the overall study; Volume II presents facility and stream characterization data; and Volumes III, IV and V present assessments of hazards to ecosystems, the general public and occupational personnel, respectively.

2 FACILITY AND STREAM CHARACTERIZATION

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2.1 OVERVIEW

The Lurgi/Fischer-Tropsch process was chosen as the basis of the assessment, because it is a proven technology, currently operating on a commercial scale at the SASOL facility in South Africa, and has been proposed for use in the United States.

Although the characterization data base for Lurgi/Fischer-Tropsch is more extensive than those of other indirect liquefaction processes, it is largely incomplete, particularly with regard to the types and concentrations of trace elements and trace organics in treated and untreated waste streams. A data base of potential environmental releases from a commercial scale Lurgi/Fischer-Tropsch facility was developed in the initial phase of the assessment to provide a basis for assessing the health and environmental implications of such a facility. The data hase was developed in several steps:

 identification of classes of chemical compounds associated with indirect liquefaction that are known or suspected to be hazardous to humans or ecosystems;

 design of a hypothetical commercial-scale Lurgi/Fischer-Tropsch facility;

3) development of a mass balance for the hypothetical facility;

 selection of priority streams for the assessment, based on toxicity, probability of release to the environment and uniqueness to indirect liquefaction processes;

5) characterization of priority streams.

The method and results of the streams characterization effort are summarized in this chapter. A more detailed description of data sources, assumptions and methodology is presented in Volume II of the report.

2.2 IDENTIFICATION OF CLASSES OF COMPOUNDS OF ENVIRONMENTAL CONCERN

Representatives of Oak Ridge National Laboratory, Argonne National Laboratory, Battelle Pacific Northwest Laboratory, and

International Research and Technology Corporation selected several classes of process stream components to emphasize in the analysis. These classes of compounds and elements, listed in Table 2-1, were selected because they had been associated with coal liquefaction and gasification processes, and were known or suspected of posing hazards to human health or the environment.

TABLE 2-1

STREAM COMPONENTS SELECTED FOR INCLUSION IN THE ANALYSIS

Aliphatics, alicyclics and fatty acids	Nitrogen Oxides
Ammonia .	Nitrosamines
Aromatic amines	Oils
Benzene and substituted benzenes	0xygen heterocyclics
Carbon monoxide	'. <sup>''</sup> Phenols
Carbonyl sulfide	Polynuclear aromatics
Hydrogen cyanide	Sulfur heterocyclics
Hydrogen sulfide	Sulfur oxides
Mercaptans	Tars
Nickel carbonyl	Trace elements
Nitrogen heterocyclics	-

2.3 DESIGN OF HYPOTHETICAL COMMERICAL-SCALE LURGI/FISCHER-TROPSCH FACILITY

A hypothetical Lurgi/Fischer-Tropsch plant processing low sulfur Wyoming subbituminous coal was designed to provide the basis for estimating the types and quantities of pollutants that might be released from a commercial facility. The plant configuration, developed by engineers at Oak Ridge National Laboratory, was based largely, though not exclusively upon information in a report prepared by the Mobil Research and Development Corporation, <u>Research Guidance Studies to</u>

# Assess Gasoline from Coal by Methanol-to-Gasoline and Sasol-type Fischer-Tropsch Technologies.<sup>165</sup>

The hypothetical facility was designed to process approximately 28,000 tons per stream day (TPSD) of as-received Wyoming subbituminous coal. The proximate and ultimate analyses heating value, and trace element content of the feed coal are presented in Table 2-2.

A simplified block flow diagram of the plant is presented in Figure 2-1. A list of plant process and waste streams is presented in Table 2-3.

#### 2.3.1 Process Description

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Sized coal  $(\pm \frac{1}{2}$  to 2") is gasified in Lurgi gasifiers at 450 psig using steam and oxygen to yield a raw synthesis gas (syngas) product. The raw syngas exits the gasifiers at 900° F. This gas is cooled and scrubbed to remove the attendant particulates, tars, oils, phenols, ammonia, and water. These components, which together are called gas liquor, are separated from the gas in the gas/liquor separator. The partially cleaned syngas is then split into two streams; one stream is further cooled while the other stream undergoes shift conversion to adjust the H<sub>2</sub>/CO ratio such that this ratio of the combined gas stream is in the desired range for the Fischer-Tropsch reaction. The two streams are then comingled and further purified using the Rectisol process to remove the sour gases (H<sub>2</sub>S and CO<sub>2</sub>) and naphtha from the syngas.

The cleaned gas from the Rectisol process is fed to the Fischer-Tropsch reactors where it is catalytically converted (over a proprietary iron catalyst), to mainly aliphatic hydrocarbon products. The raw products from the Fischer-Tropsch reactors are further processed and upgraded using conventional petroleum refinery processes to produce the plant product slate (see Table 2-4). Details of the product upgrading section have been omitted from the flowsheet because: 1) product upgrading consists of conventional petroleum refinery-type processes; and 2) the major unknowns regarding environmental and occupational

COA	L ANALYSIS, HEATI	NG VALUE,	AND TRACE	ELEMENT CONTENT	* :
,	Proximate analy	sis, as-rec	eived bas	is, wt.% <sup>165</sup>	
				,	<u>ې</u> ا
			.00 1		:
Volatile	e matter	•	22.1		
Fixed Ca	arbon				۰.
Ash ;	<u>.</u>		5.1		
Moisture	2 '	_	28.0		
	T	otal	100.0		1
Ultima	te analysis, mois	ture and as	sh-free (M	AF) basis (wt.%)	165
Carbon			74.45		
Hydrogen	<b>n</b>	•	5.10		
Ovuron	•		19.25		
Nitzogo	•		0 75		
Sulfur	1		0.45		
Sarrar	Т	otal	100.00		
	Heating va.	lue, MAF ba	sis, (Btu/	(1b) <sup>165</sup>	
High hea Low hea	ating value ting value		. 12,720 12,236		
	Trace elemen	t_content,	dry basis	(PPM) <sup>74</sup>	
Ag	0.06-0.43		Мо	2.2	
As	0.57-1.2	<i>₹</i> .	Mn	2.8-3.4	
В	32		Ni.	1.7-14	
Ва	87		P	-	
Be	0.71-0.8		РЪ	0.51-12	
Br	-		Rb	···	•
Ca	0.31-0.8		Ru	_	
Ce	-		Sh	0.08-1.5	
6	0 55		50	-	
00 Cr	6 2-16 ·		So.	0.33	
0) Co	- 0		Ce Cn	0.1/	
65 6.	8 0-10		Сн Ст	-	
งน ซ	0.7-1V 65-67		נט. ידיט	- ·	
r C-			14 To	_	
Ga	-		TG	0.88	
Ge	-		U	U+00 10-16	
нg	0.11-0.1/		V T	10-14	
I	-		W	-	
In	-		Y	-	
La			Zn	0.23-8	
Li	3.6-15.0		Zr		
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PROCESS AND ENVIRONMENTAL STREAMS OF INTEREST\*

F-T Product Upgrading F-T Product Upgrading P-T Product Upgrading F-'f Product Upgrading P-'f Product Upgrading . Coal Lockhopper SOURCE Streams 18-23 Ray Cas Shift Utological Treatment Stream 36 Stream 70 Stream 60 Stream 45 Stream 47 Stream 49 Strcom 44 leater Stack Cas Lockhopper vent Gas Emmissión9 STREAM NAME Leachare from Bioisludge CO<sub>2</sub> Purge Gas cachate from Haste Stream Evaporat ive Losses Evaporative Losses Evaporat lve Lasses Spent Shift Catalyst Evaporutive Losses CO2 OFF Gas Slolog leal Sludge Evaporative Evaporative Off Gas Lossea 06569 del STREAM 66 89 5 20 7 22 2 74 3 76 11 78 62 3 3 63 Streams 40,41,42,57,58 Biological Treatment Countyet Proparation Biological Treatment Alcohol Recovery Alcohol Recovery Ammonia Recovery Amonia Recovery Reverse Osmusis Phonol Recovery. Phenel Recovery Reverse Osmosis Stretford Unit F-T Catalyse Catalyst Propa Spont F-7 Gatalyst F-T Synthests Rectisol Unit F-T Synthesis Rectisol Unit Sol fland 1 48 Nuere Stoam Generator Ash Iland Ing **Julibual day** Gas Liquor/ Separation Iland I Ing Gas. Cooling SOURCE Huste Steam Gas Cooling Gas/1.1quor Separation Separation Gas/Liquor Generator 13 .011/Tar Free Liquor Concentrated Waste Phenol-Free Liquor Treated Effluent Incincration Gas STREAM NAME Aqueous Liquor licavy Alcohol Ash/Scruhher Studge Haste Liquor Vaste Liquor Ammon ia-Free Waste Liquor Catalyst Rau Material Vaste Liquor Slulce Water Vaste Liquor Naste Liguor Naste Liquor **Waste Water** Biulugical Effluent Waste Alr Sour Cas Vent Cas Amnon I.a Produce Phenols 1.Lquor 0115 Tars' STREAM' . • 46 35 35 33 39 7 42 **Ç** 44 Ş? 47 48 49 3 5 5 3 š 55 26 57 58 5 99 61 62 63 F-T Product Upgrading F-T Product Upgrading Utilities Generation F-T Product Upgrading F-T Product Upgrading F-T Product Upgrading F-7 Product Upgrading Vaste Steam Generator Ut 11 Lt Les, Ceneration Utilluies Generation ULLILLES Ceneration Utilities Generation Cas/Liquor Separator Gos/Liquor Seperator Utilities Concracion **Gas Recumpression/** Coal Preparation Coal Preparation Coal Preparation Coal Preparation FIscher-Tropsch Synthes Ls Air Separation Air Separation Streams 13 614 Ash Lockhapper Separator Rectisol Unit **Nash Conler** Gas Cooling Gus Cooling Bag llouse Dag Nouse Caslffer SOURCE Distillare Fuel Dil Cooled Shifted Cas Coal Pili. Leachate Ash & SÓ<sub>2</sub> Scrubber Studge ugicive Emissions Evuporative Losses leaerator Losses STREAM NAME Flscher-Tropsch Indersized Conl lenvy Fuel Oll lake-up Water Combined Gas **Purified Gas** lashed Gas Cooled Cas Couled Cas Ash Shurry Sized Coal Cost Dusc Products Stuck Gal () avdovn Feed Cual i i crogen Casoline ent Gas tau Gas Uaygen Steam ,<sup>2</sup> LPG 5475 0as 80 STREAM <u>5</u> <u>,</u> 8 R 6 2 = 5 14 5 16 2 18 5 23 22 53 2 5 26 27 28 23 E 25 ž 21

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\*Stream numbers, names and sources are keyed to the flow diagram in Figure 2-1.

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Product	Amount
SNG, MMSCF/SD*	. 173
C <sub>3</sub> LPG, BPSD <sup>**</sup>	1,707
C <sub>4</sub> LPG, BPSD	146
Gasoline, BPSD	13,580
Diesel fuel, BPSD	2,307
Heavy fuel oil, BPSD	622
Mixed alcohols, BPSD	1,825
Sulfur, TPSD	61
Anhydrous ammonia, TPSD	103
Total product, BPSD FOE <sup>†</sup>	44,950
	· ·

\* MMSCF/SD = Million standard cubic feet per stream day \*\*BFSD = Barrels per stream day † FOE = Fuel oil equivalent at 6 x 10<sup>6</sup> Btu/barrel fuel oil

health concerns are associated with the front-end (i.e., syngas production section) of the process.

The acid gases from the various processing steps are sent to the sulfur recovery unit where elemental sulfur is recovered using the Stretford process. The sulfur produced is sold as plant product. Tail gas from the Stretford process is incinerated in the plant boiler.

Boiler stack gas cleanup facilities reduce SO<sub>2</sub> to 0.2 pounds per million Btu of fired heat. In addition, an electrostatic precipitator is included to reduce the particulate matter to 0.1 pound per million Btu of fired heat duty.

The gas liquor recovered in the syngas cleanup steps is collected and processed further to separate the oils, dust, tars, crude phenols, and ammonia from the water. The recovered water undergoes additional treatment prior to reuse in the process. Waste products recovered from the gas liquor are disposed of as indicated below.

Oils and tars are recovered from the waste water by settling and decantation. The oils are processed further in the product upgrading section to yield additional plant products; the tars are incinerated in the plant boiler. Crude phenols are recovered from the wastewater by using the Phenosolvan process. The crude phenols are incinerated in the plant boiler. Anhydrous ammonia is recovered for sale by using the Chemie-Linz/Lurgi process.

The wastewater from the ammonia recovery step is biologically treated to reduce its BOD and COD levels by reducing the residual organics present in the water. The water is then subjected to a reverse osmosis treatment to reduce its metal salts content prior to reuse in the process. The biosludge (from the biological treatment step) is disposed of with gasifier ash in the mine.

### 2.3.2 Facility Environmental Controls

A wide variety of controls have been proposed for use in coal conversion facilities. The environmental controls specified in the hypothetical plant, presented in Table 2-5, were selected as representative of the types of controls that have been proposed. Many alternative controls are available or under development. Selection of specific controls will depend upon the overall plant design, sitespecific conditions, and economics.

The wastewater treatment philosophy in the hypothetical plant was to achieve zero discharge and recover contaminants as by-products whenever economically feasible. The wastewater treatment system specified for the hypothetical plant is similar to the treatment schemes at the SASOL Lurgi plant, and those incorporated into the design of proposed commercial Lurgi facilities in the U.S.

# ENVIRONMENTAL CONTROLS IN THE HYPOTHETICAL PLANT

•		
LIGOLD STREAD		
STREAM	CONTROL_PROCESS	
Coal Pile Leachate (27)	Tar/Oil Separator	
Ash Quench Sluice Water (38)	Reverse Osmosis	
Tar/Oil Separator Effluent (46)	Phenol Recovery (Phenosolvan)	
Phenol Recovery Effluent (48)	Ammonia Recovery (Chemie Linz Lurgi)	
Ammonia Recovery Effluent (50) Biotreatment Effluent (52)	Biological Treatment (Activated Sludge) Reverse Osmosis	
Reverse Osmosis Brine (53)	Evaporation Pond	•.
Reverse Osmosis Permeate (54)	Used in Cooling Tower	
Cooling tower biowadwn (Sc)	used to quench Ash	$\cdot$
	2	
GASEOUS STILEAM	<u>3</u>	
STREAM	CONTROL PROCESS	
Coal Preparation Dust (24)	Bag House	
Utility Stack Gas (28) Cooling Tower Atmospheric	Line Scrubbing/ESP	1
Emissions (29)	Pakeup water freatment	
Ash Lockhopper Vent Gas	Venturi Scrubber	
Rectisol Sour Gas (55)	Sulfur Recovery/Incineration	
Stretford Tail Gas (36)	Incineration in Utility Boiler	
F-T Heater Stack Gases (66)	Incineration in Utility Boiler	
F-T Upgrading Offgas (68)	Incineration in Utility Boiler	
Coal Lockhopper Vent Gas (72) C_LPG Storage Emissions (73)	Venturi Scrubber Pressure Vessel	
C4LPG Storage Emissions (73)	Pressure Vessel	
Gasoline Storage Emissions (73) Distillate Fuel Ail Storage	Floating Roof	1
Emissions (73)		ľ
Heavy Fuel Oil Storage Emissions (73) Alcohol Storage Emissions (74)	Cor, Roof Floating Roof	
F-T Oil Storage Emissions (75)	Fixed Roof	
F-T Tar Storage Emissions (76)	Fixed Roof	F
Ammonia Storage Emissions (77)	Pressure Vessel	
SOLID STREAMS	<u>.</u>	
STREAM "	CONTROL PROCESS	
Utility Boiler Ash (33)	Disposal in Mine	1
Gasifier Ash (34)	Disposal in Mine	1
Spent F-T Synthesis Catalyst (63)	Reclamation	1
Wastewater Treatment Bicsludge (70) Spent Shift Catalyst (79)	Disposal in Mine Reclamation	1
	······································	1

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A variety of control processes are used to control atmospheric emissions, including bag houses, lime slurry scrubber, electrostatic precipitator (ESP), venturi scrubbers, sulfur recovery, incineration, and special vessels for storing products and by-products.

Solid waste streams from the hypothetical plant are disposed of in the mine. Spent catalysts are reclaimed.

2.4 DEVELOPMENT OF FACILITY MASS BALANCE

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The mass balance for the facility was developed by staff engineers at Oak Ridge National Laboratory. The mass balance is presented in the Appendix (Table A-1). Mass flows of major stream components are based largely, though not exclusively, on Base Case 2 of the Mobil report.<sup>165</sup> Estimates of mass flows of minor stream components were based on a variety of data sources and engineering judgements and were used largely to identify hazardous streams that should be characterized in more detail.

#### 2.5 SELECTION OF PRIORITY STREAMS FOR THE ASSESSMENT

Selection of priority streams for the hazard assessment was based on consideration of three factors: 1) the probability of release to the environment; 2) the presence of hazardous components; and 3) flow rates. The presence of hazardous components and flow rates were taken from the mass balance. Each stream was assigned a probability of release to the environment from high to low. All facility streams designed to be released directly to the environment were assigned a high probability of release. Internal streams were assigned a probability of release based on evaluation of six stream parameters: temperature; pressure; presence of corrosive materials; presence of leak- or failureprone components in stream containment (e.g., valves); housekeeping requirements; and maintenance requirements. The probability of release assigned to each stream is presented in the Appendix (Table A-3).

Classes of toxic components expected in Streams with a high or medium probability of release are summarized in the Appendix (Table A-4).

Streams with a high probability of release and toxic components, were selected for further evaluation.

#### 2.6 CHARACTERIZATION OF PRIORITY STREAMS

Review of the literature indicates that characterization data for releases from commerical-scale Lurgi/Fischer-Tropsch plants are very limited. No experimental data regarding specific constituents in treated effluents from commercial-scale Lurgi/Fischer-Tropsch processing of Wyoming subbituminous coal are available. Priority streams have been characterized using data from a variety of sources. The assumptions, data and methods used to characterize each stream are discussed briefly in the following sections.

### 2.6.1 Characterization of Aqueous Streams

Aqueous streams characterized in the analysis`are presented in Table 2-6 and Figure 2-2. The assumptions, methodology and data utilized in characterizing each stream are discussed in the following sections.

<u>Raw Gas Liquor</u> (Stream 43) - Coal, steam and oxygen are fed to the Lurgi gasifier. Raw synthesis gas (mostly  $H_2$ , CO, CO<sub>2</sub>, and CH<sub>4</sub>), condensible organics (Lurgi tars and oils), and steam are produced. This stream is cooled, thus condensing the tars, oils, and steam. This liquid stream, called raw gas liquor, is sent to the Tar/Oil Separation Unit where the aqueous portion, which contains dissolved organics and trace elements, is separated from the immiscible tars and oils. The aqueous effluent from the Tar/Oil Separator Unit is called gas liquor.

Raw gas liquor (Stream 43) is the key liquid stream of interest because it represents the largest and most highly contaminated wastewater stream in a Lurgi/Fischer-Tropsch plant. It is also the major influent to the wastewater treatment facility in the plant; the types and quantities of constituents present in Stream 43 largely determine the types and quantities of pollutants which will be present in the liquid and solid effluents from the wastewater treatment facility (i.e., streams 53, 54, 70 and 71).





AQUEOUS STREAMS CHARACTERIZED IN THE ANALYSIS

AQUEOUS STREAMS CHARACTERIZED IN THE AM	NALYSIS
STREAM NAME	STREAM NUMBER*
Raw gas liquor	43
Coal pile leachate	27
	46
Phenol recovery unit effluent	<u>_</u> 48
Ammonia stripping unit effluent	50
Biological treatment unit effluent	52
Reverse osmosis concentrate	53
Reverse osmosis permeate	54
Ash sluice water	38
Fresh make-up water to cooling tower	··· 31
	-

\*Stream numbers refer to the plant block flow diagram (Figure 2-1) and table of plant streams (Table 2-3).

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The concentrations of trace elements in Wyoming subbituminous coal on a moisture free, whole coal basis were identified in the literature.<sup>74</sup> The quantities of these trace elements in the aqueous portion of the raw gas liquor then were calculated based on experimental trace element distribution coefficients developed for Lurgi at SASOL presented in Table 2-7.

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The concentrations of trace organics also were calculated for the aqueous portion of the raw gas liquor. First the organic compounds likely to be present were identified. This information came from three sources: test runs of a dry ash Lurgi gasifier using Montana Rosebud coal in Westfield, Scotland<sup>173</sup>; gas liquor samples from SASOL<sup>18</sup>; and characterization data for coal tars produced by a laboratory bench-scale gasifier using Wyoming Subbituminous coal.<sup>33</sup>

· · · ·	* - · · ·	`.	· · · · · · · · · · · · · · · · · · ·	<u> </u> `
5 Element	Ash	Liquor	Tar	Oil
Be	33.3	53.3	17.0	0.3
В.	90	8.8	2.0	0.0
ν.	99.9	0.1	'0.0	/ 0.0
Mn	99.9	0.2	0.0	0.0
Ni		0.4	0.0	0.0
As	× 26.9	67.2	1.9	3.9
Cd	51.9	45.5	0.6	1.4
SЪ	50.0	45.0	3.8	0.6
Ce	99.9	0.1	0.0	0.0
Hg	51.9	41.6	6.4	0.6
РЪ	94.2	1.7 .	4.3	0.0
Br	10.0	88.9	0.1	0.0
F	56.3	43.8	0.0	0.0
Cl	52.6	47.4	0.3	0.0

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The data from Westfield and SASOL, although not complete characterizations of the gas liquor stream, provided quantified estimates of the compounds that were identified. The data from the laboratory gasifier study provided the amount of each organic compound produced per pound of coal) gasified. Next, solubility data were used to estimate the amounts that would be dissolved in the aqueous portion of Preliminary research results at Oak Ridge National the stream. Laboratory<sup>87</sup> indicate that compounds with 4 or more rings reached 100% of their equilibrium solubility while aliphatic compounds and compounds with 3 or less rings reached only 10% of their equilibrium solubility = These findings were incorporated into the calculations. Estimated concentrations of constituents in the raw gas liquor are presented in Table 2-8.

These data may be subject to considerable error and their The SASOL and Westfield data have been reliability is uncertain. assumed to be representative of the hypothetical plant. However differences in feed coal composition and gasifier operating conditions may affect the concentrations of pollutants in the gas liquor. The estimated concentrations of substituted benzenes, PNAs, acridine and mercaptans, which were based on the RTI study data, are uncertain because several factors could not be considered. These factors include differences in composition of tars from commercial-scale Lurgi gasifiers and the RTI bench-scale unit; partitioning of compounds between water and tar/oil phases of the gas liquor; tendency of polynuclear aromatic hydrocarbons to adsorb to particulate matter; and the greater solubility of PNA in organic-solvent-water mixtures than in pure water.87

<u>Coal Pile Leachate</u> (Stream 27) - The concentrations of trace elements in the coal pile leachate were taken from the literature.<sup>32</sup> The reliability of these data is uncertain because the coal type, coal composition, and conditions of measurement were not reported.

Concentrations of organics were not included in the data, but are assumed to be negligible due to a low Chemical Oxygen Demand in the

# Estimated Concentrations of Constituents in the Raw Gas Liquor

CONCENTRATIONS IN	STREAM CONCENTRATIONS (ppm)					
CONSTITUENTS	RAW GAS LIQUOR (STREAM 43)	COAL PILE LEACHATE (STREAM 27)	ASH SLUICE Water Blowdown (Stream 38)			
TRACE ELEMENTS Arsenic Boron Beryllium Cadmium Fluorine Lead Mercury Manganese Nickel Vanadium	0.55 (1) 1.9 (1) 0.29 (1) 0.25 (1) 2.0 (1) 0.14 (1) 0.049 (1) 0.047 (1) 0.0038 (1) 0.0096 (1)	0.01 (2) 0.01 (2) 0.005 (2) 0.023 (2) 0.027 (2) 110.0 (2) 0.32 (2)	0.02 (3) 0.00064 (3) 0.09 (3) 0.0003 (3) 0.5 (3) 0.5 (3) 0.35 (3)			
CARBOXYLIC ACIDS Acetic Acid Propanoic Acid Butanoic Acid 2-Methylpropionic Acid Pentanoic Acid 3-Methylbutanoic Acid Hexanoic Acid	$\begin{array}{cccc} 171. & (4) \\ 26. & (4) \\ 13. & (4) \\ 2. & (4) \\ 12. & (4) \\ 1. & (4) \\ 1. & (4) \\ 1. & (4) \end{array}$					
BENZENE AND SUBSTITUTED BENZENES Biphenyl Ethylbenzene Indan Toluene 1,2,4 Trimethylbenzene 0-Xylene	0.7 (5): 15. (5) 8.9 (5) 50. (5) 6. (5) 18. (5)					
MONOHYDRIC PHENDLS Phenol 2-Wethylphenol 3-Methylphenol 4-Methylphenol 2,4-Xylenol 3,5-Xylenol	3100. (6) 340. (6) 420. (6) 300. (6) 120. (6) 50. (6)					
DIHYORIC PHENOLS Catechol 3-Methylcatechol 4-Methylcatechol 3,6-Dimethylcatechol Resorcinol 5-Methylresorcinol 4-Methylresorcinol	550. (6) 400. (6) 385. (6) 45. (6) 275. (6) 65. (6) 36. (6)	2				

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# TABLE 2-8 (CON'T)

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CONCENTRATIONS IN	ST	REAM CONCENTRATIONS (ppm)	,		
STREAMS	RAW GAS LIQUOR (STREAM 43)	COAL PILE LEACHATE (STREAM 27)	ASH SLUICE WATER BLOWDOWN (STREAM 38)		
POLYNUCLEAR ARCMATICS					
Acenaphthylene Anthracene Benz(a) Anthracene Benzo(g,h,i)perylene Benzo(a)pyrene Chrysene Fluoranthene Fluoranthene Fluoranthene Paphthalene Phenanthrene Phenanthrene Pyrene	0.4 (5) 0.1 (5) 0.003 (5) 0.004 (5) 0.004 (5) 0.002 (5) 0.2 (5) 0.2 (5) 3.2 (5) 0.004 (5) 0.1 (5) 0.2 (5)	-			
<u>SULFUR HETEROCYCLICS</u> Methylthiophene Thiophene		. /	*		
NITROGEN HETEROCYCLICS Acridine 2,4-Dimethylpyridine 2,5-Dimethylpyridine 2-Methylpyridine 3-Methylpyridine 4-Methylpyridine Pyridine Quinoline	$\begin{array}{cccc} 2.2 & (7) \\ 1. & (4) \\ 1. & (4) \\ 70. & (4) \\ 25. & (4) \\ 6. & (4) \\ 117. & (4) \\ 45. & (4) \end{array}$		e.		
OXYGEN HETEROCYCLICS Benzofuran Dibenzofuran		Arrent and a second			
<u>MERCAPTANS</u> Methanethiol	20. (7)				
AROMATIC AMINES Aniline	12. (4)	<u> </u>			

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Estimate based on SASOL distribution coefficients (71).
Reference 32
Reference 170
Reference 18
Estimate based on KTI data (33). Limited by compound solubility.
Reference 173
Estimate based on RTI data (33). Limited by compound production rate.

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leachate (9 mg/1). Further research is needed to verify this assumption.

<u>Tar/Oil Separation Unit Effluent</u> (Stream 46) - In the Tar/Oil Separation Unit the aqueous portion of the raw gas liquor is separated from the tars and oils, and after combining with the coal pile leachate stream it is sent to the Phenol Recovery Unit. No removal of dissolved trace elements or dissolved organics occurs in the Tar/Oil Separation Unit.

<u>Phenol Recovery Unit Effluent</u> (Stream 48) - Removal efficiencies reported in the literature<sup>18,152</sup> are 99.5% for monohydric phenol, 60% for polyhydric phenols, and 15% for most other organics. There were no reports of trace element removals occuring along with the phenol extraction.

<u>Ammonia Recovery Unit Effluent</u> (Stream 50) - No data were found for the removal efficiency of ammonia from the dephenolized gas liquor, or for the removal of organics and trace elements as unwanted contaminants with the ammonia stream. It was assumed that ammonia removal would be in the 90+% range and that no organics or trace elements would be removed with the ammonia, although some removal of volatile organics during stripping operations has been reported.

<u>Biological Treatment Unit Effluent</u> (Stream 52) - Data relating to the removal of organics and trace elements in a biological treatment unit came from a variety of sources. The percent oxidation of phenol, catechol, resorcinol, o-, m-, and p-cresol, and 2,4-, and 3,5-xylenol achieved in three hours by phenol-acclimated bacteria came from a 1964 study by Tabak.<sup>174</sup> Removal efficiencies for other organic compounds and trace elements came from an analysis of laboratory-scale activated sludge treatment of Hygas wastewater and numerous other studies. Widely different removal efficiencies often were reported by different researchers for the same compound, indicating the importance of operating conditions in the biological reactor (e.g. residence time, type of bacteria present, and whether the bacteria were acclimated to the wastewater). Some studies also noted that some of the components of the wastewater were toxic to the bacteria.

Reverse Osmosis Unit Effluents (Concentrate-53 and Permeate-54) - The feed to the reverse osmosis unit consists of two streams, effluent from the biological treatment unit (Stream 52) and ash sluice water The percent removal of organics by reverse osmosis was (Stream 38). taken from the report by Concentration Specialists, Inc.47 These results were based upon the use of a polyamide membrane, zero dissociation of the molecules, and zero recovery. Zero recovery corresponds to the highest solute rejections possible. Data on metals rejection were obtained primarily from two sources: Bostwick<sup>16</sup> reported percent rejection of metals with a cellulose acetate membrane, and Gaddis<sup>67</sup> reported rejection of metals in textile wastewater with poly Based upon the rejection data discussed above ether/amide membranes. and on assumed 80% recovery (80% permeate, 20% concentrated waste), the concentrations of organics and trace elements in the permeate and concentrate (waste stream) from the reverse osmosis unit were calculated.

The effluent from the reverse osmosis unit  $\frac{1}{1}$  is recycled for cooling tower water make-up.

<u>Ash Sluice Water</u> (Stream 38) - The concentration of each trace element in the ash sluice water was assumed to be equal to the concentrations of trace elements in first column volume leachate fractions of ash from Lurgi gasification of Montana Rosebud coal.<sup>170</sup> The data were assumed to give a good approximation of Wyoming subbituminous coal because the composition, trace element content and heating value of both coals are similar. No information could be found concerning the presence of organics in Lurgi gasifier ash; however, analysis of Lurgi ash slurry supernatant indicates that the COD is low (i.e., 2 ppm) at natural pH conditions. Therefore the concentration of organics is assumed to be low, but research is needed to verify the assumption.

Evaluation of Estimated Pollutant Concentrations in Aqueous Streams - Characterization data for aqueous streams are summarized in Table 2-9. Chemical constituents in raw gas liquor are listed in Column 1. Estimated concentrations are listed in Column 2. Column 3 lists the overall removal efficiency of each constituent (and class) as the raw gas liquor and coal pile leachate proceed through tar/oil separation, phenol recovery, ammonia recovery and biotreatment. The resultant constituent concentrations in the biotreatment effluent (Stream 52) are presented in Column 4. Constituent removal efficiencies in the reverse osmosis unit are presented in Column 5. The concentrations of constituents in reverse osmosis effluents (i.e., permeate - Stream 54 and concentrated waste - Stream 53) were estimated by applying the removal efficiencies (listed in Column 5), adjusting for inclusion of the Gasifier Ash Sluice Water (Stream 38), and assuming a permeate to concentrate ratio of 80:20. The results are presented in Columns 6 and 7.

Column 8 presents an expected range of pollutant concentrations in coal conversion wastewaters.<sup>212</sup> Comparison of estimated concentrations (Column 2) with the expected values (Column 8) indicates that most of the estimated values fall within the feed ranges. However, there are several exceptions. The estimated concentration of arsenic is a little below the feed range, while estimated levels of cadmium, lead, mercury, PNAs and quinoline are slightly greater than the feed range.

Column 9 presents ranges of effluent concentrations that can be considered as covering possible standards that may exist for released waters at the time (5 to 15 years) when commercial-sized plants can be expected to be deployed. The high end of the range corresponds to the present situation or that anticipated for the immediate future. Considerable uncertainty exists as to how far toward the lower end of the range the standards may go. Although the specified ranges are for released water, they do provide a benchmark for evaluating the reasonableness of the pollutant concentrations in treated water from the wastewaters treatment section (i.e., reverse osmosis permeate - Stream 54). Comparison of the estimated effluent concentration (Column 7) with

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Characterization Data for Aqueous Streams

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ESTIMATED CONCENTRATION FOR DISCIPACION HATERS (PDm)	10 <sup>-6</sup> -10 <sup>-3</sup> -5-0 10 <sup>-3</sup> -1 10-5-10 10-5-105	·••=	001-				.055
EXPECTED FEED RANGE FOR COAL CONVERSION HASTENATER (ppm)		· · ·	0-2,000				50-10,000
STREAM 54 REVERSE USMUSIS PERMEATE (piuu)	028 	3.1 .34 .18 .028 .17 .014	3.85	.0016 .42 1.47	2.307		3.36
STREAM 53 REVERSE OSMOSIS HASTE (ppu)		13. 2.5 1.2 1.1 094	18,18	.62 2.9 3.3 3.3	24.12	2.00. 	41.08
REMOVAL EFFICIENCY REVERSE OSMOSIS (1)		ធំនំនំធំធំធំធំធំ	54.	53.53 53.53 53.53	63.	ĸĸĸĸĸ <i>₽</i> ₽ĸĸĸ <i>₿</i> ĸ₿8	75.
STREAM 52 BLOEFLUENF (pm)		7.4 1.1 .55 .086 .043	9.75	1.5 1.3 1.3 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5	9,58	6.7 6.7 6.7 6.7 6.7 7 6.7 7 6.7 7 6.7 7 6.7 7 6.7 7 6.7 7 6.7 7 7 6.7 7 7 7	15.98
REMOVAL EFFICIENCY LIQUOR SEPARATION THROUGI BLOTHEATHENT (2)	ទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទទ	8.59 95.8 95.8 95.8 95.8 8.8 8.8 8.8 8.8 8.8	95.8	75. 92. 92.	90.2	99.99 99.99 99.99 99.99 99.99 99.99 99.99 99.28 88.3 88.3 89.99 90.2 88.3 89.99 90.2 88.2 88.2 88.2 89.2 90.2 88.2 88.2 88.2 8 90.2 88.2 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	0.06
STREAM 43 RAM GAS LIQUOR (ppn)	55 29 19 14 0047 0088	13. 13. 12. 13. 13. 13. 13.	225.	.7 15. 8.9 18.	92.6	550 550 3300 3300 3300 3300 3300 3300 3	6,096.
CIEMICAL CONSTITUENE	<u>TRACE ELENENTS</u> Arsenic Beryllium Dorom Cadmium Lead Manganese Marganese Markel Markel Vanadium	CAUBOXYLIC ACIDS Acetic Acids Propanotc Acid Butanoic Acid Butanoic Acid Pentanoic Acid Pentanoic Acid Iteranoic Acid	Total Carboxylic Acids	BLNZENES Bipheny 1 Ethylbenzene Indan Toluene O Xylene	Total Benzenes	PitENOLS Catechol 3.6-Dimethylcatechol 3.6-Dimethylcatechol 4.Nethylcatechol 2.Nethylphenol 3.4echylphenol 4.Nethylphenol 4.Nethylphenol 6.Nethylresorcinol Ruenol 8.sorcinol 8.sorcinol 2.4-Xylenol	Total Phenols

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TABLE 2-9 (continued)

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EST IMATED CONCENTRATION FOR DISCINNIGE WATERS (ppm)		10-6-10-3		····	<u>ن</u> ا ا	.1-10.			
EXPECTED FEED RANGE FOR COAL CONVERSION HASTEMATER (FOIN)		0.l-l0.	, VADIFS		к	10-600.	91.00	.01-10.	
STREAM 54 REVERSE OSMOSIS PELNEATE (PJUN)	.0003 .00075 .000075 .000002 .000002 .0000015 .00015 .00015 .00075 .00075	.0081		01.2	.0091 .00023 .00023 .016 .016 .0116 .0122	.038	.0022	7200°	
STREAM 53 REVERSE DSMOSTS MASTE (pim)	2.8 0.012 0.012 0.0012 0.0012 0.0012 0.0012 0.0012 0.0012 0.00012 0.00012 0.00012	3.163	5.9 .	6.6%		. 336	.025	620.	•
REHOVAL EFFICIENCY REVERSE OSNOSIS (Z)	ត់ទំនំទំនំតំតំតំតំតំតំតំតំតំតំតំតំ តំទំនំតំតំតំតំតំតំតំតំតំតំតំតំតំ	99.	90. 50	ъч.		69.	74.	74.	
STREAM 52 BIOEFFLUENT (pum)	.015 0000 00005 000035 000035 000035 000035 000035 000035 000035 0006035	6960.	6'L	۲.۱۷	.0051 .001 .001 .001 .0026 .0026 .002	.142	<i>1</i> 600.	.0097	
REMOVAL EFFLCTENCY LIQUOR SEPANATION THROUGH BIOTIKEATMENT (Z)		79.		91.5	899999999999 8999999999999999999999999	99.94	6.66	99.9 -	
STREAM 43 RAM GAS L IQUOR (ppm)	32.52.000 32.52.0000 32.52.0000 32.52.0000 32.52.0000 32.52.0000000000000000000000000000000000	4.42	22.	> 22.	12. 26. 26. 120. 45.	281.	9.6	9.5	
CIICMICAL CONSTITUENT	POLYNUCLERR ARDINTICS Acenaphthylene Anthraceure Beurzolg, hanthraceure Beurzolg, hijuerylene Benzolg, hijuerylene Chrysene Fluoranthene Fluoranthene Perview Premathrune	Total PNAs	ORGANIC SULFUR Mechanethio Thiophenes *	Total Organic Sulfur	<u>ORGNALC BASES</u> Ant Tine 2.4-Dimethy lpyridine 2.5-Methy lpyridine 3-Methy lpyridine 4-Methy lpyridine Pyridine Dyridine	Tutal Organic Bases	<u>POLYCYCLIC DAS:S</u> Quineline	Total Polycyclic Bases	OXYGEN IET <u>ERDEYCL ECS</u> Beitzofuran <sup>a</sup> Dib <u>en</u> zofurana

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the effluent goal ranges (Column 9) indicates that most of the estimated values fall within the ranges. There are a few exceptions. Estimated concentrations of arsenic and phenols are high, while the estimated concentration of boron is low. Overall, the results appear to be in line with the expected values listed in Column 9.

## 2.6.2 Characterization of Gaseous Streams

Data on the characterizaton of gaseous streams are very limited in the published literature. No experimental data could be found regarding specific gaseous constituents from Lurgi/Fischer-Tropsch processing of Wyoming subbituminous coal.

Gaseous streams selected for the analysis are presented in Table 2-10 and Figure 2-3. The analysis focused on two general classes of pollutants (trace elements and organic compounds) that have been identified as potential causes of concern in gaseous streams from coal conversion facilities.

In general the types and quantities of pollutants in each stream reported here were derived from the literature and modified, as necessary, to reflect the composition of the feed coal, and size of the conceptual plant used in this analysis. The types and quantities of trace elements present in the gaseous streams were estimated using trace element characterization data for Wyoming subbituminous coal. The distribution of trace elements from the gasifier is based on SASOL data<sup>72</sup>, (see Table 2-7) and the distribution of trace elements from the utility boiler is based on data from the WESCO Coal Gasification Project<sup>202</sup> (see Table 2 -11). The assumptions and methodologies used to characterize each stream are discussed below.

Utility Stack Gas (Stream 28) - Utility stack gas is generated by burning undersized coal, and Lurgi gasifier tar and phenols in steam boilers. Particulates in the stack gas are reduced by an electrostatic precipitator to 0.1 pound per million Btu of fuel fired. Lime slurry scrubbing is employed to reduce SO<sub>2</sub> emissions to 0.2 pounds of SO<sub>2</sub> per





GASEOUS STREAMS CHARACTERIZED IN THE ANALYSIS

TABLE	2-10	

STREAM NAME	STREAM NUMBER*
Utility stack gas	28
Cooling tower atmospheric losses	29
Coal lockhopper vent gas emissions	72
Evaporative losses (Streams 18-23)	73
Evaporative losses (Stream 60)	74
Evaporative losses (Stream 45)	75
Evaporative losses (Scream 44)	76
Evaporative losses (Stream 47)	77
Evaporative losses (Stream 49)	78
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\*Stream numbers are keyed to the plant block flow diagram (Figure 2-1) and table of plant streams (Table 2-3).

TABLE 2-11

	DISTRIBUTION OF	TRACE ELEMENTS	FROM UTILITY B	OILERSON
TRACE ELEMENT		DISTRIBUTION OF	TRACE ELEMENT	INTO FACILITY (%)
	BOTTOM	ESP	STACK GAS	ATMOSPHERIC
	ASH	FLY ASH	SCRUBBER	EMISSIONS
As	4.4	94.6	0.8	0.2
Be	16.9	82.2	0.7	0.2
Ca	16.0	82.7	1.0	0.3
F	1.2	26.8 .	57.6	14.4
Hg	4.4	13.0	0.1	82.5
Рb	9.7	89.3	0.8	0.2

DISTRIBUTION OF TRACE ELEMENTS FROM UTILITY BOILER<sup>202</sup>

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million Btu of fuel fired. The flowrates of the major constituents of the stack gas ( $CO_2$ ,  $N_2$ ,  $O_2$ ,  $H_2O$ ,  $SO_x$ , and  $NO_x$ ) have been calculated by Schreiner<sup>165</sup> and are presented in Table 2-12.

#### TABLE 2-12

COMPONENTS OF UTILITY STACK GAS (STREAM 28)

Component	Flow Rate (1b/hr.)	Concentration (WE.%)
co2 <sup>165</sup>	2,739,799.	39.46
N <sub>2</sub> + Inerts <sup>165</sup>	3,632,785.	52.33 -
0 <sub>2</sub> <sup>165</sup>	71,264.	v 1.03
H <sub>2</sub> O <sup>165</sup>	497,676.	
$S_{x}^{-}$ (as $S_{2}^{-}$ ) <sup>165</sup>	960.	. 138. ppm
N0,154	176.	25. ppm
Trace Elements*		
Arsenic	•0008	.0001 ppm
Beryllium	-00085	.0001 ppm
Cadmium	.0007	.0001 ppm
Fluorine	2.875	.41 ppm
Mercury	•0541	.0078 ppm
Lead	•0086	.0012 ppm
		÷

\*Estimate based on trace element content of Wyoming Subbituminous coal and trace element distribution coefficients for coal gasification<sup>72</sup> and utility boilers<sup>202</sup>.

Any of the trace elements found in the coal may be present in the stack gas; however, sufficient information was available to quantify the concentrations of only six of the trace elements (As, Be, Cd, F, Hg, and Pb). The quantity of each trace element entering the utility boiler with the coal was calculated from 'che flow rate of the coal and the trace element composition of the coal. The quantity of each trace element entering the utility boiler in the tar from the gasifier was calculated from the flow rate of the tar and the trace element distribution data from SASOL.<sup>72</sup> The quantity of each trace element emitted with the stack gas was calculated from the distribution of trace elements from the utility boiler. Results are presented in Table 2-11.

<u>Cooling Tower Atmospheric Losses</u> (Stream 29) - Cooling tower losses to the atmosphere consist of evaporation and drift. The quantity of losses to the atmosphere was estimated to be 2,413,000 lb/hr.<sup>165</sup> The composition of the stream was estimated by assuming that the atmospheric losses would contain the pollutants present in the two streams combined to provide cooling tower make-up water, i.e., reverse osmosis permeate (Stream 54) and fresh make-up water (Stream 31). The estimated composition of Stream 29 is presented in Table 2-13.

Coal Lockhopper Vent Gas Emissions (Stream 72) - Coal is fed to a lockhopper which must be pressurized to the same pressure as the gasifier before the coal can be discharged into the gasifier. The gas used for pressurization is the gasifier product gas after cooling and separation of the condensibles. When the coal locks are depressurized to receive the next load of coal, the pressurization gas is released. The portion which is released down to atmospheric pressure is recompressed and fed back into the gas processing stream. The small quantity of gas escaping during the charging operation of the coal locks is not recompressed due to the presence of air, and is exhausted through a venturi scrubber to the atmosphere. It is assumed that the flow rate of lockhopper gas vented to the atmosphere is equal to .1% of the total flow rate of product gas entering the gas/liquor separator.74 The composition of the vent gas is derived from several studies. 33,74,173 Estimated flow rates of classes of components of the Coal Lockhopper Vent Gas are presented in Table 2-14.

<u>Evaporative Emissions from Product and By-Product Storage</u> (Streams 73-78) - Flow rates of evaporative emissions from product and by-product storage are estimated based on unpublished EPA data. The EPA data, developed for a smaller size plant, have been adjusted to correspond to the product and by-product production rates of the

<u>,</u>

FABLE	2-13
<b>FABLE</b>	2-13

COMPONENTS OF COOLING TOWER ATMOSPHERIC LOSSES (Stream 29)

Stream Component	Flow Rate (1b/hr)	Concentration (PPM,)
Ammonia	6.0E+1	4.9E-1*
Arsenic	4.4E-2	3.5E-4
Beryllium	2.1E-2	1.7E-4
Boron	-s= <b>1.3E−1</b> "	- 1.1E-3
Cadmium	2.4E-2	1.9E-4
Fluorine	9.5E-1	8.0E-3
Lead	4.6E-2	3.7E-4
Mercury		2.9E-5
Nickel	1.2E-3	9.8E-6
Vanadium	3.7E-4	· 2.9E-6 🕹
Acetic Acid	5.1E 0	4.1E-2
Aniline	3.2E-3	2.6E-5
Butanoic Acid	2.9E-1	2.3E-3
Carechol	2.3E 0	1.9E-2
Hexanoic Acid	2.2E-2	1.8E-4
Pentanoic Acid	2.6E-1	2.2E-3
Phenol	° 6.7E-2	5.5E-4
Propanoic Acid	5.3E-1	4.3E-3
Pyridine	4.4E-3	
Resorcinol	7.7E-1	6.3E-3
2-Methylphenol	1.8E-2	1.5E-4
2-Methylpropionic Acid	4.4E-2	3.5E-4
2-Methylpyridine	2.6E-2	2.2E-4
2,4-Dimethylpyridine	3.7E-4	2.9E-6
2,4-Xylenol	1.6E-2	1.3E-4
2,5-Dimethylpyridine	- 3.7E-4	2.9E-6
3-Methylbutanoic Acid	2 <b>.</b> 2E-2	1.8E-4

\*The "E" is used to signify scientific notation (i.e.,  $4.9E-1 = 4.9 \times 10^{-1}$ ).

	Ч. м	TABLE 2-13 (Concluded)	
	Stream Component	Flow Rate (1b/hr)	Concentration (PPM,)
· ·	3-Methylcatechol	0.0E O	O.OE O
	3-Methylphenol	1.1E-2	9.2E-5
	3-Methylpyridine	9.5E-3	7.6E-5
	3,5-Xylencl	2.3E-1	1.8E-4
	3,6-Dimethylcatechol	1.9E-1	1.5E-3
	4-Methyl Resorcinol	1.5E-1	1.2E-3
	4-Methylcatechol	1.6E 0	1.3E-2
	4-Methylphenol	1.6E-2	1.3E-4
6	4-Methylpyridine	2.1E-3	1.8E-5
ي. د	5-Methyl Resorcinol	2.6E-1	2.2E-3
-	Acenaphthylene	4.8E-4	3.9E-6
	Anthracene	1.2E-4	9.6E-7
	Benz(a)Anthracene 🕄	1.2E-5	9.6E-8
	Benzo(a)Pyrene	4.8E-6	5.9E−8
	Benzo(e)Pyrene	4.8E-6	3.9E-8
	Benzo(g,h,i)Perylene	3.7E-7	2.9E-9
	Biphenyl	2.4E-3	2.0E-5
	Chrysene	2.4E-6	1.9E-8
•	Dibenzofuran	3.2E-3	2.5E-5
	Ethylbenzene	6.7E-1	5.5E~3
	Fluoranthene	2 <b>.</b> 4E-4	1.9E-6
	Fluorene .	2.4E-4	· 1.9E-6
	Indan	3.2E-2	2.5E-4
•	Methanethiol	2.6E-1	2.2E-3
	Naphthalene	1.1E-2	9.2E-5
	Perylene	4.8E-7	3.9E-9
	Phenanthrene .	1.2E-4	9.6E-7
	Pyrene	2.4E-4	1.9E-6
	Quinoline	3.4E-3	2.8E-5
	Toluene	2.2E 0	1-8E-2
	o-Xylene	7.7E-1	6.2E-3

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Component	Flow Rate (1bs/hr)	Concentration (wt. %
N <sub>2</sub>	8-4	.002
H <sub>2</sub> 0	1422	36.37,4
	1483	37.934
CO	602	15.399
H2	89	2.277
CH <sub>4</sub>	206	5.269
C <sub>2</sub> H <sub>4</sub>	<sup>:</sup> 2 <b>.</b> 5	0.064
H <sub>2</sub> S .	5.4 .	0.138
cos	.12	0.003
Ni(CO)4	•006	1.5 ppm
Tars	4.4	113
Oils	38.5	<b>.</b> 985
Naphtha	15.7	-402
Phenols	5.2	-133
Ammoni.a	8.1	•207
Fatty Acids	1.0	.026
Mercaptans	.02	5.1 ppm
Thiophenes	.016	4.1 ppm
HCN	.008	2.0 ppm
Aromatic Amines	.004	. 1.0 ppm
Nitrosamines	•002	• •5 ppm
PAHs	.002	•5 ppm
Trace Elewents	.002	•5 ppm
TOTAL	3909.4	99.79

TABLE 2-14					
COAL.	LOCKHOPPER	VENT GAS.	(STREAM 72)		

conceptual facility used in this study. Estimated emission rates are presented in Table 2-15.

2.6.3 Characterization of Solid Streams

No experimental data could be found regarding specific constituents in solid wastes from Lurgi/Fischer-Tropsch processing of Wyoming subbituminous coal.

Solid streams selected for this analysis are presented in Table 2-16 and Figure 2-4.

The analysis focused on two classes of pollutants that have been identified as potential causes of environmental concern in solid streams from coal conversion facilities: trace elements and organic compounds.

In general the types and quantities of pollutants in each stream were:

- estimated from the literature and modified, as necessary, to reflect the size of the conceptual plant and the composition of the feed coal used as the basis of this analysis, or
- estimated by assuming that pollutants will be removed from the gaseous and liquid streams by the mechanism of adsorption onto the solid wastes going to disposal.

The data, assumptions and methodologies employed in characterizing each stream are discussed in the following sections.

<u>Boiler Bottom Ash, Fly Ash, and Scrubber Sludge</u> (Stream 33) -The flow rates of major stream components are taken from Schreiner.<sup>165</sup> All 22 of the trace elements present in Wyoming subbituminous coal will be present in these streams, however data on the distribution of trace elements were available for only six (As, Be, Cd, F, Hg, Pb).

The quantities of the six trace elements fed to the boiler were calculated using the feed rate and trace element composition of the coal and tar fed to the utility boiler. The trace element composition of the tar was determined from trace element distribution data from SASOL.<sup>72</sup>

(SIREANS /	5-76)	
Product/By-Product	Flow Rate (1bs/hr.)	
Diesel Oil (Stream 73)	0.513	
Fuel Oil (Stream 73)*	St 0.014	
Lurgi Oil (Stream 75)**	12.625	
Lurgi Tar (Stream 76) <sup>†</sup>	6.750	
Alcohol (Stream 74) <sup>††</sup>	1.500	
Phenols (Stream 77) <sup>§</sup>	3.750	
Ammonia (Stream 78)	No Data	
C <sub>3</sub> LPG (Stream 73)	No Data .	
C <sub>4</sub> LPG (Stream 73)	No Data	
· · ·		
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EVAPORATIVE EMISSIONS FOR PRODUCT AND BY-PRODUCT STORAGE (STREAMS 73-78)

\* The fuel oil is reported to be all  $C_7$  + hydrocarbons.<sup>165</sup>

\*\* The following compounds are reported to be present in the Lurgi oil: benzene, thiophene, toluene, xylenes, phenol, alkyl phenols, naphthalene, cresols, benzothiophene. (EPA unpublished data.)

<sup>†</sup> The following compounds are reported to be present in the Lurgi tar: napththalene, anthracene, fluoranthene, phenanthrene, pyrene, cresols, phenol, fluorene, dibenzofuran. (EPA unpublished data.)

<sup>††</sup>The alcohol is reported to be ethanol and  $C_3$  + alcohols.<sup>165</sup>

S The following phenolic compounds are expected to be present: phenol, catechol, resorcinol, methylcatechol, methylresorcinol, cresols, xylenols.
# TABLE 2-16

# SOLID STREAMS CHARACTERIZED IN THE ANALYSIS

STREAM NAME	STREAM	NUMBER*
Utility ash and SO <sub>2</sub> scrubber sludge		33
Gasifier ash		34
Combined ash and scrubber sludge		36
Spent Fischer-Tropsch catalyst		63
Leachate from ash (Stream 36)		69 <b>**</b>
Biological sludge	•	70
Leachate from biosludge (Stream 70)		71**
Spent shift catalyst		79

\*Stream numbers refer to the plant block flow diagram (Figure 2-1) and table of plant stream (Table 2-3).

\*\*Liquid stream, but emanating from a solid waste after disposal.

 $(\Sigma)$ 



The distribution of these trace elements between the bottom ash, fly ash, scrubber sludge, and stack gas was determined from the literature.<sup>202</sup> Estimated components of utility ash and FGD sludge are presented in Table 2-17.

<u>Gasifier Ash</u> (Stream 34) - Schreiner<sup>165</sup> reported the flowrates of the major classes of components in the gasifier ash (see Table 2-18). Data were available for calculating the concentrations of nine of the 22 trace elements that are expected to be present in the gasifier ash. The feed rates of these trace elements (As, Be, Cd, F, Hg, Pb, B, Ni, V) to the gasifier were calculated from the feed rate of coal and the trace element composition of the coal. The estimated (amounts of these trace elements in the gasifier ash are based upon the distribution of these trace elements among the ash, liquor, tar, and oil, as reported in data from SASOL.<sup>72</sup>

# TABLE 2-17

Component	Flow Rate (1b/hr.)	Concentration (wt.%)
Minerals	20,950	89.00
Sludge	2,577	10.95
Trace Elements	-	
Arsenic	0.003	.13 ppm
Beryllium	0.003	.13 ppm
· Cadmium	0.003	.13 ppm
Fluorine	11.50	0.049
Mercury	.0001	.0042 ppm
Lead	0.034	1.4 ppm
TOTAL	23,538.54	ι,

#### COMPONENTS OF UTILITY ASH AND FLUE GAS DESULFURIZATION SLUDGE (STREAM 33)



TABLE 2-18 COMPONENTS OF GASIFIER ASH (STREAM 34)

Component	, Flow Rate (1b/hr.)	Concentration (wt. %)
Water	199,486	65.89
Minerals	96.031	31.72
Coal	7.038	2.32
Sulfur	•66	.022
Trace Elements		
Arsenic	0.44	1.5 ppm -
Beryllium	0.36	1.2 ppm
Cadmium	0.57	1.9 ppm
Fluorine	51.64	•017
Mercury	0.12	.39 ppm
Lead	15.48	51 ppm
Boron	39-43 /	.013
Nickel	19.05	63 ppm
Vanadium	19.15	63 ррш
TOTAL	302,767.24	

Dewatered Gasifier Ash, Boiler Ash, and Scrubber Sludge to Final Disposal (Stream 36) - Schreiner<sup>165</sup> reported the flow rates of the major classes of materials in this stream. The flow rates of nine of the trace elements were calculated by summing the flow rates contributed by each stream and subtracting the amounts of these trace elements removed by solubilization of the element in the ash sluice water. The amount of trace element solubilized was computed from first column volume leachate fractions of Mentana Rosebud subbituminous coal ash from the Lurgi gasifier in Westfield, Scotland.<sup>170</sup> Components of Stream 36 are presented in Table 2-19.

Spent Fischer-Tropsch Catalyst (Stream 63) - Commercial Fischer-Tropsch catalysts include cobalt (fixed-bed) and iron (fixed- and fluidbed). Although iron is the base for both units, catalyst preparation and formulation are extremely different and very specific for each unit type.

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# TABLE 2-19

### COMPONENTS OF DEWATERED GASIFIER/UTILITY ASH AND SCRUBBER SLUDGE TO DISPOSAL (STREAM 36)

Components	Flow Rate (1b/hr.)	Concentration (wt. %)
Water	20,000	13.6
Minerals	116.989	79.7
Coal .	7,038	4.8
Sulfur	66	•05
Other	3,542	1.8
Trace Elements		
Arsenic	0.81	5.5 ppm
Bryllium	0.79	5.4 ррш
Cadmium	. 0.81	5.5 ppm
Fluorine	·· 66.73	.045
Mercury	0.13	.88 ppm
Lead	19.67	.014
Boron	. 39.4	•027
Nickel	19.02	.013
Vanadium	19.15	.013 .
TOTAL	147,802.00	99.9

Although spent F-T catalyst is removed periodically, not continuously, Schreiner has reported the replacement rate of F-T catalyst on a continuus basis to be 30T/SD. Catalyst life is approximately 50 days.

Due to the proprietary nature of the catalyst, very limited information is available regarding chemical composition, economics of regeneration or metal recovery from spent catalysts. It appears that the cobalt based catalyst could be economically recovered. Onsite regeneration of iron based catalyst may not be practical or economical, and hence it may be either sent to metals/catalyst vendors or disposed of as a solid waste. No data are available regarding leachate characteristics.

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Leachate from Ash and FGD Sludge (Stream 69) - Characterization data are not available for leachate from ash generated by Lurgi gasification of Wyoming subbituminous coal. Leachate data are available for ash from Lurgi gasification for Montana Rosebud subbituminous coal, and are assumed to be representative of this study.

Two potential sources of inconsistency are 1) differences in characteristics of Rosebud and Wyoming subbituminous coal and ash, and 2) the leachate data are derived from first column volumne leachate fractions, while the ash in the hypothetical facility is quenched, slurried and dewatered prior to disposal in the mine. Differences in composition of the Wyoming and Rosebud coal are not expected to result in significant differences in leachate composition for two reasons. First, the two coals are very similar regarding trace element concentrations, heating value and proximate analysis (the most` significant difference being ash content (dry basis) which is 12.9% in Rosebud and 5.58% in Wyoming subbitumious coal). Second, a recent evaluation<sup>82</sup> of coal conversion solid waste and leachates indicates that there is a strong similarity between the soluble constituents found in a solid waste and the treatment it undergoes, i.e., ashes from Lurgi gasification of three dissimilar coals (Illinois #5, Illinois #6 and Rosebud) yielded nearly the same soluble constituents. .

The composition of ash leachate is presented in Table 2-20.

The flow rate of ash/sludge leachate (Stream 69) is estimated by calculating the acreage required for disposal, and assuming that the net annual precipitation falling on the suface of the disposal area leaches into the ground and becomes leachate from the disposal area. An average: net annual precipitation of 30 inches is assumed for the calculation. The estimated flow rate of leachate is 6,985,000 gallons per year or 0.85 liters/second.

To simplify the analysis it is assumed that most of the soluble portion of trace elements would be leached from the ash and sludge within the first year, and that concentrations of trace elements in

TABLE 2-	-20
COMPONENTS OF LEACHAT	E FROM COMBINED
ASH AND SCRUBBER SLUD	GE (STREAM 69) <sup>170</sup>

Component	Flow Rate (1b/hr)	Concentration (ppm)
Aluminum	1.3E-3	2.0E-1
Arsenic	1.3E-4	2.0E-2
Cadmium	4.3E-6	6.4E-4
Copper	2.0E-4	3.0E-2
Iron	1.1E-2	1.6E O
Mercury	2.0E-6	3.0E-4
Manganese .	3.3E-3	5.0E-1
Nickel	2.3E-4	3.5E-2.
Lead	6.0E-4	9.0E-2
Selenium	4.0E-4	5.0E-2
Zinc	1.9E-5	2.9E-3
Other Trace Elements	No Data	No Data
Organics	No Data	No Data

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leachate would be negligible after the first year. The validity of this assumption is not known. However, evaluation of the leachability of solid wastes from Lurgi gasifiers<sup>170</sup> indicates that many potentially toxic trace elements are rapidly mobilized during ash quenching. Ash quenching, slurrying and subsequent dewatering, as specified in the hypothetical plant, may reduce the concentration of trace elements in leachate generated at the ash disposal site. Research in this area is necessary to determine the actual period of time during which leaching will produce significant concentrations of trace elements.

<u>Biological Sludge</u> (Stream 70) - The flow rate of wastewater to the biological treatment unit was taken from the Mobil report.<sup>165</sup> The amount of sludge production was calculated from data in the WESCO EIS Report<sup>202</sup>, which reported wastewater flow rate and the production rate of dry biological solids. This information was used to calculate the sludge production rate in terms of pounds of solids/gallon of

wastewater. Using this factor and the assumption that the sludge would be disposed of 20% wet, the sludge production rate of the hypothetical facility is estimated to be 3,900 lbs/hr.

Data regarding the chemical composition of biosludge from indirect liquefaction facilities are not available. Quantities of several potential contaminants in the biosludge are estimated by assuming that biorefractory compounds in biotreatment influent (Stream 50) are removed via non-destructive mechanisms and incorporated into the biosludge.

Data from the literature  $^{154,212}$  indicate that although PAHs are biorefractory, high removal efficiencies are achieved by the mechanism of adsorption and sedimentation. Seventy percent removal of PAHs with 2 rings and ninety percent removal of PAHs with more than 2 rings were assumed. The lower removal efficiency for 2-ring PAHs was assumed because of the higher solubility of the less complex PAHs. Removal efficiency of trace elements in the biological sludge came from a variety of sources.  $^{31,64,212}$  Results of the calculations are presented in Table 2-21.

Leachate From Biosludge (Stream 71) - Biosludges generated by -wastewater treatment operations may be disposed of by incineration, landfilling, or soil application. Incineration has been successfully practiced for municipal and industrial biosludges for many years and is a reasonable alternative where land is not available for sludge disposal. Most sludges, however, are disposed of in conventional landfills and it is expected that the biosludges from indirect liquefaction facilities would also be handled in a similar fashion. In this study it is assumed that the biosludge is combined with ash and other solid wastes, and buried in the mine.

No data are available regarding chemical characteristics of leachate from biosludge generated by treating wastewaters for indirect facilities.

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ĭ	Compound	Flow Rate (1b/hr)	Concentration (ppm)
A	cenaphythlene	156.4	0.61
Å	inthracene .	38.5	0.15
Ŧ	Benz(a)anthracene	3.8	0.015
E	Senzo(g,h,i)perylene	0.1	0.00046
ł	Benzo(a)pyrene	1.6	0.0061
ł	Benzo(e)pyrene	1.6	0.0061
C	Chrysene	0.8	0.003
J	fluoranthene	79.5 N	0.31
<u></u> ]	Fluorene	79.5	0.31
۳ ۱	Naphthalene	974.3	. 3.80
1	Phenanthrene	38.5	0.15
1	Pyrene	76.9	0.30
4	Arsenic	141.0	0.55
1	Beryllium	.74.4	0.29
(	Cadmium	41.0	
. 1	Mercury	11.8	0.046
	Lead	51.3	0.20

TABLE 2-21 COMPONENTS OF BIOLOGICAL SLUDGE (Stream 70)

<u>Spent Shift Catalyst</u> (Stream 79) - The average useful life of shift catalyst is 3 years. An indirect liquefaction plant producing 45,000 BPSD fuel oil equivalent would have an inventory of about 400 tons of shift catalyst.<sup>165</sup> Therefore once every 3 years 400 tons of spent shift catalyst is replaced. The spent catalyst may either be disposed of or reclaimed. Because of the high price of cobalt it is likely that spent shift catalyst will be reclaimed. The trace element content of spent shift catalyst is given in Table 2-22.

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TABLE	2-22

Constituent Elements	Concentration (% wt)
Cobalt	5–15
Molybdenum	15-25
Sulfur	5-20
Carbon	· 5–10
Arsenic	0.7-7.0
Lead	4-10
Selenium	0.3-1
Mercury	0.2-0.8

SPEND SHIFT-CATALYST (Stream 79)

# 2.6.4 Streams Not Addressed

Several streams with an estimated high probability of release were not characterized in detail because they were not unique to the process, or they were not expected to contain hazardous components or not enough data were available. These streams include undersized coal (Stream 3), nitrogen from air separation (Stream 5), raw gas from coal gasifier (Stream 7), dust from coal preparation (Streams 24 and 25) , coal preparation bag house vent gas (Stream 26), deaerator losses for utility gasification (Stream 30), ash handling vent gas (Stream 35), waste air from biotreatment (Stream 51), waste steam from FT upgrading (Stream 65) and  $CO_2$  purge gas from FT upgrading (Stream 67).

#### 3 ECOLOGICAL ASSESSMENT

## 3.1 INTRODUCTION

Process waste streams generated by a /commercial-scale indirect liquefaction facility employing Lurgi/Fischer-Tropsch technology may affect surrounding aquatic and terrestrial ecosystems. In this assessment of ecological risks, process waste streams that have a reasonable possibility of directly or indirectly entering the environment are identified. For each of these process waste streams, inorganic and organic contaminants most likely to occur are identified and their expected concentrations following appropriate dilution in the ambient environment are calculated. These concentrations are compared with background concentrations and various toxicologic benchmarks (such as, biological effects thresholds, legal standards, and federal recommended criteria) to determine the potential hazards associated with each contaminant or class of contaminants.

#### 3.2 METHODOLOGY

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The assessment of risks to aquatic and terrestrial ecosystems from an indirect liquefaction facility was accomplished using the approach illustrated in Figure 3-1. Many assumptions, qualifications and uncertainties were reflected in this analysis: variations in the processes, controls, scale, feedstock, and operating conditions of a facility are expected to alter significantly the chemical constituents and toxicity of the process, product, and waste streams. The many analytical assumptions and caveats associated with the ecological assessment are described in Volume III of this report and will not be dealt with in detail in this chapter. Most of these assumptions and caveats contributed to a conservative, though not necessarily "worst case" analytical approach.

Additive, antagonistic, and synergistic interactions among various toxic components of complex mixtures are probable; how ver, these interactions could not be estimated reliably, and were not considered in this report. This analysis also assumed negligible loss



FIGURE 3-1

or transformation of process constituents by biological, physical or chemical processes.

In the first step of the ecological assessment process, seven waste streams were characterized as having a reasonable possibility of contaminating the environment surrounding a commercial facility:

o Ash (stream 36)

o: Ash leachate (stream 69).

- o Biosludge from the biological treatment unit (stream 70)
- o Concentrated waste solution from the reverse osmosis unit (stream 53)
- o Utility stack gases (stream 28)
- o Cooling tower atmospheric losses (stream 29), and
- o Lockhopper vent gases (stream 72).

The chemical constituents of these streams were identified as a second step based upon the stream characterization data presented in Volume II, and summarized in Chapter 2 of this report.

In the third step, each constituent was placed in one of three categories depending upon the availability of relevent toxicologic benchmarks and estimated concentrations in the process waste streams.

The first category (Category "A") had no entries because it represented empirical data from a commercial scale Lurgi/Fischer-Tropsch facility indentical to the conceptual reference facility (and such data are not yet available). The second category (Category "B") included substances that were quantified in waste streams, based upon data from processes similiar to the reference facility. Category "C" included process constituents that were inadequately characterized owing to a lack of quantitative estimates or toxicologic benchmarks.

For constituents in Category "B", ambient environmental concentrations were estimated by applying dilution factors, as identified in Table 3-1, to the estimated waste stream concentrations. These projected ambient environmental concentrations then were compared with various toxicologic benchmarks.

TABLE 3-1 SUMMARY OF THE IMMEDIATE FATE, MAJOR ASSUMPTIONS, AND DILUTION FACTORS ASSOCIATED WITH THE ECOLOGICAL ASSESSMENT OF INDIRECT LIQUEFACTION WASTE STREAMS

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∕, ∕	RECEIVING MEDIA	ASSUMPTIONS	DILUTION FACTOR
28-Utility Stack	Atmosphere	- SAM/I model utilized	235
,		<ul> <li>Dilution factor is calculated for gaseous stream being discharged into the atmosphere at a flow rate of 8.75 x 10<sup>5</sup> em/sec</li> </ul>	<u> </u>
29-Cooling Tower Evaporative losses and drift	Atmosphere	- Partitioning of contaminants between drift and evaporative losses could not be evaluated	Only emission rate data available
		- Contaminants in drift would tend to become enriched on the surface of vegetation and in soils	
	•	- Therefore no dilution factor was calculated	
53-Reverse Osmosis Waste	Small Surface Stream	- Stream is released to an evapora- tion pond	<b>4</b>
		- All of the dissolved components are subsequently released into a small (locfs) surface stream through over- flow or percolation through the soil	74
· · · · · · · · · · · · · · · · · · ·		- Surface water contamination is greatest threat	
		- Losses of contaminants through physical chemical and biological processes are negligible	

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SUMMARY OF THE IMMEDIATE FATE, MAJOR ASSUMPTIONS, AND DILUTION FACTORS ASSOCIATED WITH THE ECOLOGICAL ASSESSMENT OF INDIRECT LIQUEFACTION WASTE STREAMS

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	STREAM	RECEIVING MEDIA	, ASSUMPTIONS	DILUTION FACTOR
	69-Leachate from	Landfill, then	- Ash is deposited in a landfill	333
	Gasifier and Utility Ash	a small stream	<pre>- Leachate (0.85 1/sec) from ash enters a small stream flowing at 10 cubic feet/sec (283 1/sec)</pre>	
	-	ب بو بو	- Concentrations for leachate derived by Shriner <sup>170</sup> for a leachate obtained processing Montana Rosebud coal in the modified dry-ash Lurgi gasifier in Scotland	
ć	- 	بر	- No attenuation of leachate by soil	· ·
		•	- No dilution of leachate prior to entry into receiving stream	
÷			- Losses of constituents through physical, chemical and bilogical processes are negligible	
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TABLE 3-1 (Cont.) SUMMARY OF THE INMEDIATE FATE, MAJOR ASSUMPTIONS, AND DILUTION FACTORS ASSOCIATED WITH THE ECOLOGICAL ASSESSMENT OF INDIRECT LIQUEFACTION WASTE STREAMS

STREAM	RECEIVING MEDIA	ASSUMPTIONS	DILUTION FACTOR,
70-Biosludge	Landfill, then	- Biosludge is deposited in landfill	283
	י אוומדד ארדכמוו	- All contaminants ultimately reach a small receiving stream	
	· .	- Complete mobility is assumed for trace metals and organics in biosludge	
		- Flow rate of receiving stream is 283 1/sec	
		- Concentration of constituents in biosludge is not reduced by physical, chemical or biological processes	
72-Lockhopper Vent Gas	Atmosphere	- SAM/1 Model utilized	24,000
		- Dilution factor calculated for a gaseous stream being discharged into the atmosphere at a rate of 493 g/s	:
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Toxicologic benchmarks used in this analysis included:

- Proposed freshwater quality criteria for protection of sensitive aquatic organisms
- Proposed estimated permissible concentrations (EPC's) for water and ecology, or air and ecology
- The lowest reported concentrations that elicit a biological response (generally sublethal)

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- Mean toxic concentrations
- Daphnia magna chronic toxicity concentration
- Threshold bioaccumulation concentrations
- Lowest observed median lethal concentrations (LC<sub>50</sub>'s)
- Most stringent criteria based upon National Primary and Secondary Ambient Air Quality Standards or NIOSH Permissible Exposure Limits (whichever is the most stringent criterion)
- Published toxicities regardless of species, endpoint, and exposure conditions.

These toxicological benchmarks are further described in Table 3-2. More relevant toxicologic data such as Maximum Acceptable Toxicant Concentrations (MATCs) and No-Observed-Effect Concentrations (NOECs), generally were not available for the pollutants of interest.

Estimated ambient environmental concentrations of waste stream constituents also were compared with average ambient concentrations of these constituents in unpolluted or "normal" environments.

Very few relevent toxicologic benchmarks were available for assessing the effects of airborne contaminants on terrestrial biota.

To assess the chemical hazards, the ratio of the projected ambient environmental concentration for each chemical constituent, or class of constituents, to the corresponding toxicologic benchmark(s) was computed. The greater the ratio, the greater the relative hazard.

# 55 TABLE 3-2

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# EXPLANATION OF TOXICOLOGIC BENCHMARKS

TOXICOLOGICAL BENCHMARK	DEFINITION
PROPOSED FRESHWATER CRITERIA (PFC)	EPA proposed freshwacer Criceria <sup>209</sup> , 210, 211
ESTIMATED PERMISSIBLE CONCENTRATION (EPC)	Ambient Level Goal. Concentration of a pollutant in emission stream which, after dispersion, will not cause the level of contam- ination in the ambient media to exceed a safe continuous exposure concentration. EPC's are one of the Multimedia Environmental Goals for environmental assessment proposed by J.G. Cleland and G.L. Kingsbury, Research Triangle Institute. EPC's are stated separately for air, water, and land effects for both human health and for ecological effects, 34, 35, 36, 37
LOWEST OBSERVED TOXIC CONCENTRATION (LOIC)	Lowest observed concentration eliciting a coxic response, regardless of type of response, species or exposure conditions.49
MEAN TOXIC CONCENTRATION	Mean concentration toxic to freshwater crustaceans unlags other- wise noted.131
DAPHNIA CHRONIC TOXICITY CONCENTRATION (DCTC)	Concentration of contaminant found by Biesinger and Christensen to elicit a 16% reproductive impairment in <u>Dapheia magna</u> , a sensitive aquatic species after 3 week exposure 12
THRESHOLD BIOACCURULATION CONCENTRATION (TBC)	Concentration of contaminant in water which could accumulate to levels in fish tissue which in turn, might prove to be barely coxic when consumed by man. These are computed by Hildebrand and Cushman <sup>39</sup> using the method of Dawson, which is based on drinking water standards (DWS), published bioaccumulation factors <sup>131</sup> and the assumed human consumption of 0.06kg of fish perday. The maximum safe daily intake by man was considered to be equivalent to the quantity of the element represented by the consumption of 2 liters of water containing the element at the DWS standard.
	Threshold Bio- accumulation(mg/liter) = UWS(mg/liter) x 2(liters water/day) 0.06 (kg fish/day) x Br
•	DWS = Drinking Water Standard BF = Bloaccumulation factor for fish
LOWEST OBSERVED LC <sub>50</sub> (LOLC)	The calculated concentration of a substance in either air or water (as separate figures) which will cause the death of 50 percent of an experimental animal population under controlled conditions and time exposure, most often 96 hours for aquatic species. References for specific compounds are given in Ecology section.
MOST STRINGENT CRITERIA (MSC)	National Primary or Secondary Ambient Air Quality Standards set by EPA: or Permissible Exposure Limits determined by NIOSH (whichever is the most stringent criterion). 80
TOXIC CUNCENTRATION (TC)	Published coxicities regardless of species, endpoint, and exposure conditions. In case of classes (e.g. PAH's) coxicities are for specific compounds (e.g. naphthalene).34, 35, 36, 37, 130

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Based upon these ratios, three degrees of concern were specified: Probable Hazards, Possible Hazards, and Unlikely Hazards, as described in Table 3-3.

In the final step, the constituents that represented the most significant hazards to aquatic and terrestrial ecosystems were identified by reviewing the various classes of hazards identified in all waste streams likely to enter the aquatic, terrestrial or atmospheric environments.

3.3 RESULTS 🚓

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Serious constraints limit the validity of comparing expected contaminant concentrations with various published toxicological results, legal standards, or recommended acceptable concentrations. Amongy these constraints are the lack of standardization among testing procedures, exposure - conditions, and test organisms; the variations in the assumptions and uncertainty associated with different toxicologic benchmarks; and the uneven quality and quantity of research directed at the various contaminants. It is even more difficult to compare the relative potential hazards among several contaminants. Ideally only results representative of identical test conditions and target species should have been used to compare the toxicity of one constituent with another. Because this was rarely possible, several toxicologic benchmarks have been used with the acknowledgement that a great deal of uncertainty is associated with these results.

The results are presented separately for each stream analyzed.

Ash and Ash Leachate: (Streams 36 and 69) - Information on ash and ash leachate produced by indirect liquefaction processes using Wyoming subbituminous, coals is not available. However, leachate data are available for ash from a similar coal-process combination, i.e., gasification of Montana Rosebud coal in the modified dry ash Lurgi gasifier in Westfield, Scotland<sup>170</sup>, and have been used in the analysis. These data are limited to trace elements and do not allow .

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# DEFINITION OF DEGREES OF CONCERN

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DEGREE OF CONCERN	DEFINITION
PROBABLE HAZARD	RATIO OF PROJECTED AMBIENT POLLUTANT CONCENTRATION TO TOXI- ICOLOGIC BENCHMARK: GREATER THAN 10
POSSIBLE HAZARD	RATIO OF PROJECTED AMBIENT POLLUTANT CONCENTRATION TO TOXI- COLOGIC BENCHMARK: 0.1 - 10.0 <u>OR</u> EXISTING DATA ARE INADEQUATE TO ASSESS THE SUBSTANCE
UNLIKELY HAZARD	RATIO OF PROJECTED AMBIENT POLLUTANT CONCENTRATION TO TOXÍ- COLOGIC BENCHMARK: LESS THAN 0.1 SUBSTANCE IS KNOWN TO PRESENT NO SIGNIFICANT TOXICOLOGIC PROBLEMS

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estimation of the hazard potential of organic contaminants in the ash. Sor the purpose of this analysis, ash has been assumed to be trucked to an off-site landfill. The leachate from the resulting ash pile has been assumed to enter into a small receiving stream (10cfs), and thereby, into the aquatic environment. When the diluted ambient environmental concentrations for the constituents of the Westfield leachate are compared to various toxicologic benchmarks, no Probable Hazards are identified (see Table 3-4). Copper and manganese are placed in the Possible Hazards category. Iron and selenium exceed average ambient freshwater concentrations but neither of these metals exceed any toxicologic benchmarks.

In order to generate an additional set of values for comparison, a hypothetical, worst-case leachate has been compiled using the highest observed concentration of each contaminant found in a literature search. of leachates from gasifier ash, regardless of coal or specific process. Again, with the exception of ammonia, only trace element data are available. Dilution factors are the same as those applied in the . case of Lurgi/Montana Rosebud coal. For this hypothetical, worst-case leachate, examination of the limited information indicates that numerous trace elements exceed average ambient freshwater concentrations (see Iron, aluminum and zinc exceed one or more toxicologic Table 3-5). benchmarks by an order of magnitude or more, and therefore are classified as Probable Hazards. Arsenic, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, silver, and vanadium are classified as Possible Hazards. Ammonia also exceeds its EPC in this worst case scenario, and is classified as a Possible Hazard.

It is extremely unlikely that a commercial facility will operate in a mode that will result in leachate values approaching this worstcase situation; therefore, the final evaluation of the hazards associated with ash and ash leachate is based on the conceptual facility design and empirical data from Westfield, Scotland.

TABLE 3-4: CASIFIER ASH LEACHATES (Streams 36 + 69):

COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS (OF Westfield coal ash leachate) WITH ECOLOGICAL BENCHMARKS

		6-32 C		1.12-2	Ţ		2.UE-3	8. 2E-3		1 20	1	7-27-0	2-30-2	1. JE-2	7-30-5	9.0E-1		1.8E-4		
r	Amblant Freshugfer Conc. (i) wg/f	. 6-AL 6		2-36-5	1.0K-3.	9. 9E-2	2.95-4	1.1E-2		1 00-0		4-46-1	. 7-30 -	10-30-7		Z, UE-4	-	4.95-2		
A/G			1 10-1	6-241-4			2.46-3			T	. 15 .	7-31-7		7-36-7		T-96-2				
<u>с</u>	Proposed Freshvater Criteria mg/t		(-aL 5	3-37.6	A. / C-4		9-95-6				- <u>1</u>	4.26-4	2 27 2			7.16-3				
A/F	•	2.0E-2	1.7E-7			1 0	1-30.6	4.5E-3		4-8E-2	C-35 7		1 26	5 56-3		3-0E-6		4.4E-4		
ů.,	Threshold Blaace(F) Conc. (F) ag/f	3.0E-2	5.01-1	-		7 AE-1		2.0E-2		L.0E-1	6-05-6	2 OE-2		2.015-2		5-2012		2.0E-2		
A/E		1.9E-3	1.28-4			1 12-9		4.2E-3		1.1E-3	-9, 0E-1	1 6E-6	2 7E-A	1-39-1				1.25-4		
es A	Daphnia Chronic Tox(G.e) conc.	<b>J.</b> 2E-1	5.2E-1			1 75-4		2-2E-2		3.8E-1	3.DE-2		1 45-1	1-08-2				7.0E-2		
ą		2.2E-4	2.05-5			5-47-5		9. OE-5		5.95-4	1.5E-4	1.25-4	7-40-1	3.35-4	7.45-5		•	<b>J.</b> 8E-6		
•	Hean Toxíc (c) Eanc.(c) mg/&	2.7				3.5E-2	0 55 1	1-32-4		8.1	1.8	1.26+1	9.05-3	3.2E-1	2.5k			2.3		
A/C		8.6E-J	2.7E-3			9.5E-3	1-31 6	1-36.2		2.46-2	9.0E-3	4. 3E-3	4.58-3	3.78-3	7.2E-3			2.9E-J		
ບ ~	Louist Ubserved Toxic (b) mg/t	7.0E-2	2.2E-2			2.0E-4	V 0E-V			2.0E-1	3.0E-2	<b>1.5E-1</b>	2.0E-4	3.0E-2	2.5E-L			1-30.6		
8/R		3, OE-3	6.05-3			4.8E-3	9_05-1			9.5E-2	2.7E-2	7.5E-2	I.8E-2	5.4E-2	3.65-2			4.75-4		
8		2.0E-1	1.05-()			4-05-4	1.05-2		ا	5.0E-1	1.0E-3	2.0E-2	5.0E-5 <sup>1</sup>	2.06-3	5.0	<i>,</i>		2-11-7		
<	Fist (milted) Post- dilution Conc.	6.0E-4	6.0E-5			1.9E-6	9.05-5			4.8E-3	2.7E-4	L.5E-3	9.0E-7	1.1E-4	1.85-4		1 75 0	0-1-0		
		TRACE ELEMENTS AlumInum	Arsente	Berv11Jum	Boron	Cadmittim	Conter		Fluorine	Iron	fread	Мапралезе	Mercury -	Nickel	Selenium	Vanaditem			TOTAL THACE ELEMENTS	1 5

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. d**tstima**čýd permissibie concentration in aquulte ecouystem<sup>34</sup> <sup>b</sup>kegardless of species, type of response, or exposure conditions<sup>49</sup>

<sup>c</sup>for freshuater crustaceans, unless ocherwise noted<sup>131</sup>

<sup>d</sup>Concentration causing 16 percent reproductive impairment after 3 veeks<sup>12</sup>

<sup>ckeference</sup> 130

 $f_{\rm Assuming}$  bioaccumulation factor of 2.3,<sup>131</sup> and drinking water standard of 0.05 mg/t <sup>205</sup>

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<sup>8</sup>References 209, 210 and 211

<sup>h</sup>Calculated from mean observed posicion values frum U.S. freshvaturu, weighted according to fruquency of ducection106

<sup>1</sup>Assumed EPC = (0.2) (NMTE of 0.250 mg/u)<sup>35</sup>

JPersonal commutcations: G.L. Kingsbury

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<sup>k</sup>for phytuplankton

<sup>1</sup>fish and Wildlife Service<sup>62</sup>

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TABLE 3-5 "WORST CASE" CASIFIER ASH LEACHATES (STREAM 69): COMPARISOM ÚF PROJECTED -DILUTION ENVIRONTRATIONS OF SUBSTANCES (N A HYPOTHEFICAL LEA

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	blued	Diluted	Erca		2.00%		ti min la	:	Threa-		Heatu		Proposed		Ambilent	
	MALME	Vent Leta	5:		Disgrout		Clumble		ploid		Toxic		Frenh-		Frenh	
	Gare	Leachate	1.14		Taxle,		Toulefly		1018		Coar.		valer		vator	
	Lenchato				Chite."		ساد/ا د مرا		i uic	•	male f		Griteria =6/f		Cone.	
- HINITIAN	6.9E-1	6. DF-6	7-06-1		7.05-2	0.0	1.05-1		- ERGE	2.151	1.1.7	2.68-1		Ì	2-36.2	3.0711
ANT RUDRY	1-48-1		4.05-2	4.51-2	1.1	1.46-3				1.15.1	2.0611	9.01-5			4-3E-1	1.461
ARSENIC	9.05	6.01-5	1.0E-2	9.05-1	2.25-2	A. IE-1 ~	5.28-1	1.75-2	5.06-3	-	1.0	2.96-3	1.72-2	1.62-1	3.56-1	2.6
<b>AALUM</b>	1.56-1		5.01-1	3.07-3	2.6	2.68-4	A. 66-1	2.78-4	<b>[.</b>	1.05-6	5.46.1	2.85-5			5-315-3	3.58-2
NERVILING .	9.02-5		1.16-2	0.25-3	1.55-1	6.0E-6		12	1.7511	5.45-6	9.87	9.25-6	1.75-4	5.35-1	1.08-5	9.0
DOROH	1.15-1		5.0	2.2E-2	6.95-1	1-39-1			1.5EH2	7.35-6	A.GELL	2.8%-3			9.96-2	1.1
CAPPELLER	1.85-4	1.95-6	A.0E-4	A. SE-1	2.0F-4	9.0E-1	1.75-4	1.1	2.06-3	9.05-2	3.56-2	5.1E-J	3.85-4	4.76-1	2.45-4	7.51-1
CHRONING	6.05-4		2-40-5	1.28-2	5.05-2	1-32-1		1.81-3	4-30-4	1.5	6.8	8.88-5			2.46-3	2.58-1
CONALT	5.75-4		5.0E-2	1.1E-2	1.05-2	5.7E-2	1.0E-2	5.7E-2	5.0E-J	1.16-1	1.0	5.75.4			4.85-4	1.2 .
TIPPER	1.25-3	9.06-5	1.05-2	1.25-1	4.05-4	0,0	2.2E-2	5.4E-2	2-30.5	5-01-2	9.55-1	1.36-3	-		1.15-2	1.18-1
FLUORINE	8.47-3	\$			2. Jk	J.7E-)				•	2,7612	<b>3.16-5</b>				
LAUN	2.6	16.3.2	5.0E-2h	5.2813	2,08-1	1.35.1	3.8E-1	6.0E-1	1-30-1	2.4E+J		3.25-1	-		3.96-2	6.761
LEAD	1-30°.0	2.15-4	1.0E-2	6.06-2	3.05-2	2.0E-2	3.0E-2	2.05-2	6-30-3	1-30-1	1.6	3.3E-4	1. JE-2	4.6E-2	4.46-3	1.4E-1
WRANESE	1.15-2	1.55-3	2.015-2	5.58-1	3.5%-1	3.15-2		2.8E-3	3.05-3	3.7	1.2611	3-25-6			3.05-2	3.76-1
I PROUNT.	6.08-6	2-30.6	S.OE-SJ	1.25-1	2.0E-4	3.01-2	J.4E-J	1.8E-3	7.05-5	B.&E-2	9.06-3 .	6.75-4	6.4E-57	9.4E-2	7.05-5	A.GE
MULTURINA	3.06-3		1.4	1.26-3	4. JENI	6.0E-5			1.7	1-86-3	1.24.5	2.56-5			2-22-2	1-31-1
NICKEL	2.36-3	1. LE-4	2.05-3	1.1	<b>J.OE-2</b>	7.7E-2	3.05-2	1.55-2	2.0E-2	1.25-1	1.25-1	7.26-3			3.15-7	
SELENTIN	1.85-4	A-38.1	5.0E-J	3.66-2	2.56-1	7.2E-4			2.0E-J	5-30.6	2.50	7.26-5	9.75-3	1.95-2	2.05-4	9.0E-1
SILVER	3.0F-5		5.05-3	6.05-3	3.05-3	1.07-2			7.15-1	4.25-5	6.45-2	6.RE-4	9-20-6	5,5	1.75-4	1.85-1
THAMRING	9-38.4				3.05-2	1.65-4					2.0 <sup>r</sup>	2.45-6			1.05-1	4.AE-3
TEN	9-20.6				3.56-1 .	2,6E-6	1.58-1	2.75-5	6.0E-4	1.55-2	1120.2	1.05-7			4.05-5	7. 16-1
TANUAL	· 5.1E-J		1-06-1	5.1E-2	Z,8	1.85-3			1.7	5.98-2	1.051 Jn	1.75-4			1.01-1	5.1
VARADIUS	2.46-2		1.56-2	3.25-1	. 0.4	5.01-3			1-30.0	2.31-1	2.46+1	1.05-3			1.46-3	1.761
SINC	5.15-2	6.7E-6	2,06-2	2.6.	J. AC-J	1.77.1	7.116-2	7.25-1	2-30.5	2.6	2.7	2-32-2			A.9E-2	1.0
A THEN BA	5.11-2		1.01-2	5.1	2.05-1	2.6E-1	Ī				3.5	1.55-2				
						And and an an an an an an an an an an an an an										

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hCalculated from mean observed positive values from U.S. freshwaters, weighted according to frequency of detection<sup>106</sup> eAssuming Bioaccumulation Factor = 2.3, <sup>131</sup> and Drinking Water Standard - 0.05  $mg/l^{206}$  $^{
m c}$ Concentration causing 16 percent reproductive impairment after 3 weeks exposure. *t*., <sup>b</sup>Regardless of species, type of response, or exposure conditions<sup> $\dot{4}9$ </sup>  ${}^{a}$ Estimated permissible concentration in aquatic ecosystems  ${}^{34}$ TABLE 3-5 (Concluded)  ${f f}_{Mean}$  concentration toxic to freshwater crustaceans  $^{131}$ <sup>g</sup>Assumes water hardness = 50 mg/l as CaCO<sub>3</sub>209,210,211 iAssumes EPC = (0.2) (MATE of 0.25 mg/l)<sup>35</sup> JPersonal communication, G.L. Kingsbury <sup>o</sup>Value is for phytoplankton <sup>n</sup>Value is for macrop%ytes Ö Ċ, <sup>m</sup>Value is for fish )) PReference 45 dReference 130 k<sub>Referer.ce</sub> 91

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<sup>q</sup>Inorganic mercury

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Biosludge: (stream 70) - Biological sludge will be generated by an indirect liquefaction facility. Because the question of its disposal is yet to be resolved, the hazard posed to ecosystems by this waste has been assessed by assuming that the sludge will be stored in or on the ground and that all of the contaminants ultimately will be released into a small (i.e., 10cfs) receiving stream. It should be noted that many potential contaminants probably will be tightly bound to soil or the solid waste matrix and will not be extremely mobile; therefore, this assumption tends to exaggerate the potential exposure. Comparisons of the resulting ambient environmental concentration for each substance in the biosludge to toxicologic benchmarks, indicate that cadmium and mercury appear to present the greatest hazards (see Table 3-6). Their ratios for EPCs, lowest observed toxic concentrations, threshold bioaccumulation concentrations and proposed freshwater criteria fall into the Probable Hazard category. Lead and arsenic also exceed these criteria, but the ratios are lower. Beryllium is present at levels greater than 700 times proposed freshwater criteria; however, its low solubility and apparent propensity to adsorb to particulates and hydrolyze to form insoluble compounds will probably result in concentrations far below hazardous levels. All of the above mentioned metals exceed average ambient freshwater concentrations.

Polynuclear aromatic hydrocarbons (PAHs) in the biosludge may also pose a problem. Of those few PAH's for which toxicity data exist, naphthalene is a Probable Hazard, exceeding the lowest observed toxic concentration by a factor of 170. The suspected carcinogens phenanthrene and fluoranthene are Possible Hazards. Lack of information on the bioaccumulation, chronic toxicity, toxic interactions, carcinogenicity and mutagenicity of PAH's, in general, prevents a conclusive evaluation of their threat to the aquatic biological community. As a class, PAH's should be considered a Possible Hazard owing to the high degree of uncertainty associated with these compounds.

	ខ	NCENTR	ATION	NITH S	ECOLO	GICAL	BENCHM	ARKS									
	A	1	A/b	J	A/C		, a/A	щ	A/E	μ.	A/F		A/C	H	A/II	-	A/I
	Ëst.	Erca	i	lawest		lovest		Hean	<u>U</u>	hronic		hold	<u>~ (</u>	ropowa	<u> </u>	mbient	
	Post- Dilution Conc	1	<u> </u>	Dbserved LC <sub>50</sub> b	<u> </u>	Dbserved Taxic		Toxic Conc.	-	Toxic Conc.	5	B10- ccum. <sub>f</sub>	0	Fresh-	и и	Fresh- vater <sub>h</sub> Conc	
	Bg/L			1/չլա		mg/2		1		- /0		Conc. Te/8		3/Sm		mg/1	
TRACE ELEMENTS																	
Aluminum						†   	T	+	+-	1					+		
Arsenic	2.4E-1	1.0E-2	2.4E-2	2.2E-2	1.1E+1	<u>2-2E-2</u>	1.15-1	3.1	7.7E-2	5.2E-3	4-6E-1	5.DE-3	4.8E+1	5.7E-2	4.2	3.5E-3	<u>6.9E+1</u>
Berv11ium	1.3E-1	1.1E-2	1.25+1	1.5.E-1	8. ZE-1	וביזטנ	8.71-1	1 B. E	1.3E-2			1.75+1	Z-9E-3	1.7E-4	2 9542	1-0E-5	1.3546
Boron																	
Codmî un	7.1E-2	4.0E-4	1.86+2	9.0E-4	7.9E+1	1.75-4	4.2E+2	3.5E-2	2.0	1.7E-4	4.25+2	2.0E-3	3.6E+1	3.8E-4	1.95+2	2.4E-4	3.0E+2
Соррег								-									
Fluorine																	
Iron	;																
Lead	8.9E-2	1.0E-1	8,ÿ.	3.4E-1	2.6E-2	3.0E-2	3.0	1.8	4.9E-2	3.0E-2	3.0	6-0E-3	1.55+1	1.3E-2	6.8	4.4E-3	2.0EH
Hanganese																	: <u>-</u> :
Hercury	2.1E-2	5-30.2	4.2E+2	5.0E-3	4.2	4.01-5	5.36+2	9.0E-3	2.3	3.4E-3	6.2	7.0E-5	3.0E+2 6	.4E-5 <sup>+</sup>	3.3E+2	7.0E-2	3.0E+2
Nickel																	
Selentur.						~											
Vanadium	•					_											
21nc						_				_							
TOTAL TRACE ELL'SENTS																	
ALIPHATICS, ALICYCLICS AND FATTY ACIDS																÷,	
Acetic Acid																	
butanoic Acid							Ì			Ī						1	
lickanoic Acid																	
3-Methvlbucanoic Acid		_			- I									1			
2. Hethvlpropanoic Acid									:								
Fentanolic Acid																	
Propanoic Acid	   					-1							Ì				
TOTAL FAITY ACIUS						- 1											
SENZENES & SUBSTITUTED		-															
PERZENFS																	
Binhuny]	:- - 													, , ,			
Ethyll engone					-	:		:		- - 		 					
Indan	, , ,	;;							•						†- 		
Toluene	;	i : : :	:	; ;	:	:			i- ;	i ; ;	-i- :						
1, 2, 4-Trizethellh. nzene	, 1	: 			:	i		i			1					:	
o-Xvlene				•									;	-			i i

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TABLE 3-6: BIOSLUDGE (STREAM 70): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL

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(continued)
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TABLE

	<	23	A/B		A/C	-	A/n;	ш	A/E		A/F	 0	V/C	=	A/II	-	1/1
-	Est.	EPC 0		Lovent		LOVCBE	2	Hean		chronic		Thres-		nagadar,		unb ten t	
	Post-			Ubserve)	<b></b> -	Toxic		Texic Conc.		Conc.		-010 		Ficel-	_	usan-	
	Conc.			nc 기/웹비		Conc.		1/Bu		1/80		Conc.	<u>.</u>	uater   mil/t		Conc.	_
PHLNOLS					İ						·   •					   	
Catecho)									1		1				Ī		
<u>J.6-Dimethylcatechol</u>											Ì		-	Ì	ļ	i	
J-Hethylcalechol					Ì						İ				Ì	Ī	
4-Huthylcacechol											Ì	Ì				Ì	
2-Methylphenol											1						
3-Hethylphanol								_	•						Ì		
4-Methylehenol																!	
4-Huthylresorcinol																	
5-Heiliv]resorcinol												İ	Ì				
Phrnol	•										 	İ		 .   			
Resorcinol					   									ļ			
2.4-Xv1en01																;	
3. 5-Xv1 enol													ļ			;	ļ
TOTAL PHENOLS											İ		ļ	İ			
FOLYRINILEAR ARONATIC							<u> </u>				 				   1		
Ac enaplit hal ene	2.7E-1		ļ										İ				
Anthracent	6.78-2				Ì	5.0	<u>1.3E-2</u> _				Ì		i			T	
beng(a)unthracene	6.78-3				Ì	1.0	<u>6.75-2.</u>  -									-	T
Benza(E.h. I) perylene	2.05-4									Ì	Ì		Ť			i	
ficitio(a) pyrene	2.7E-3			İ		•											
	2.7E-3						-								i	•	ļ
Chrysene	1.3E-3		1				-†- 										ŀ
Fluid and hene	1.4E-1	:	1		Ì	1-30.1	1.4				ļ		İ	2.56-1.	2.68-1	!	
1 hun ene	1.4E-1		1			2.0	2.8E-2		!				   		:	 ! !	1
heindet had ene	1.7	5.01-2	3.4611.	2.4	7.16-1	1.06-2	1. 2012								;	1	1
Per yl ene																:	:
"Pichanotlicence	6.7E-2			1.1	6.1E-2	1.45-2						1				;	
"Dyrune	เเรียม					1.0L11.	1.3Ľ-2.					i				:	1
TOTAL PAIL'S							•	1									
SULLIN, HUTTROCYCLICS						,				7							
Hethylihlophene	!	, ,		1				! !	1				•	;		!	
Thuphene	:	:.	:			1				:	, , ,	1 1 1	:	 . : :	•	!	
				<u>نہ</u> ا			 	Ţ		Ť I			į			T	, i

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TABLE 3-6 (continued)

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	۷		A/B	υ	V/C	4	A/D	u	A/E	1	A/F	-	A/G	-	-  5		12
	Esc. Post-	EPC <sup>a</sup>		Lovest		Lovest		Nean Toxic		Chronic		livld		Proposed Criteria	<u></u>	mbienr Fresh-	
	Conc.			LC <sub>50</sub> b		Toxic Conc.		Conc." mg/k		Conc. <sup>C</sup> mg/R		accum.f		Freish-		unter Conc.h	
	1/81					3/8				-		1,12		1/8u	. <b></b> .	mg/t	
WITHOUS IN THE EXOCICLICS															$\left  \right $		
2,4-Ulmochvlpvrldine					Ì	1	İ							~~			
2,5-Dimethylpyridine																	
2-Hethylpvridine															-		
3-Methylpyridine													T		$\left  \right $		
4-Methvlpvridine										Ì		T	T		$\left  \right $		
Pyridine										Ť	T						
Ouinoline						 				Ì					┢		
										İİ					$\frac{1}{1}$		
DXYGEN HETEROCYCLIC	<u> </u>																
Benzofuran								•									
Díbenzofuran							 						T	      .	-  	-	
					Í												
HERCAPTANS				÷				,	• ••••			÷					
Methanethiol							_										
TOTAL MERCAPTANS								<u> </u>	Ī	Ī		+				╞	
AROMATIC AMINES Aniline		 : :	<u></u>			•		_									
TOTAL AROMATIC AMINES			İ						-				1-		+		
NTTR/16 ANT NES	Ì	1.		+													
									<u> </u>								
MISCEL AREDIC									+								
Antionia				•	÷					<u> </u>							
Carbony Sulfide			İ							+		_ _     		   			
lledrauon Cuantido	<u></u>			1							 						
Hvaropen Sulfice				÷					<u> </u>							_	
Hickel Carbonyl	<del>.</del>						 ::		 					 !			
NO <sub>2</sub>		-+   			 					 	_	; - ;	 :				} 1
Part leulates					—		 ,			:	: : :	:			 	<u> </u> 	.
sox.					 			 		<u>.</u>	• !	<u>;</u>	 : :				
- Jars, Pils, Japhthe					•	•	 -		 ! !			<del> </del>   !	i				
									•	•			i				1

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# TABLE 3-6 (concluded)

<sup>3</sup>Bstimated Permissible Concentrations for Freshwater Ecosystems 5.

bExposures of 24-96 hours<sup>49</sup>, 141, 173.

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<sup>c</sup>Includes "No Effect" concentrations<sup>49</sup>, 114, 132, 139, 173

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dvalues are for crustaceans except for beryllium which represents fish toxicity data.

<sup>e</sup>Values are for <u>Daphnia magna</u><sup>12</sup>.

f<sub>Reference</sub>89.

 $g_{\rm Assumes}$  hardness = 50 mg/l as CaCO<sub>3</sub>

h<sub>R</sub>eference 106.

iInorganic mercury.

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<u>Concentrated Waste Solution From the Reverse Osmosis Unit:</u> (Stream 53) - This stream is the largest aqueous waste stream generated by the indirect liquefaction facility. Its rate of flow is nearly 100 times that of the ash leachate. Several disposal options for this stream are possible including deep-well disposal and evaporation, ponds. To facilitate comparisons of the relative ecological hazard posed by Stream 53 with the hazards posed by other streams from the conceptual plant, it has been assumed that the entire waste stream enters, and is fully diluted by a small freshwater stream (10cfs).

The limited data available indicate that the waste solu ion from the reverse osmosis unit is likely to exhibit high concentrations of several toxic trace elements and organic compounds (see Table 3-7 and 3-8, respectively). Arsenic, beryllium, cadmium, manganese, mercury, and nickel are classified as Probable Hazards, because they exceed toxicological benchmarks, by a factor of ten or more. Boron, fluorine, and lead are identified as Possible Hazards.

The total organic content of this stream, even after dilution, is relatively high (24mg/1). Data are very limited for toxicologic benchmarks for organic compounds. Phenols and polynuclear aromatics are the greatest concerns. Catechol, resorcinol, total phenols, and naphthalene, are classified as Probable Hazards; methanethiol, ethyl benzene, indan, toluene, o-xylene, and acetic acid are Possible Hazards.

Many other polynuclear aromatics and nitrogen heterocyclics are expected to be present in this waste stream, but toxicologic data are too limited to assess the degree of hazard that these compounds represented to aquatic ecosystems. For this reason they are considered constituents of potential concern.

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Utility Stack Emissions: (Stream 28) - Utility stack emissions comprise a major source of air pollutants and may represent an important regional stress to the surrounding environment. Toxic gases, particulates, and trace metals present the reatest hazards (see Table 3-5). Based upon the dilution factor derived from EPA's Source Analysis Model 1 (SAM/1) for the disperison of atmospheric emissions, maximum 1.14BLE 3-1:

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REVERSE USHUSIS HASTE STHEAMS (STREAM 53): CANIFARISON OF PRAJECTED POST-DILATION ENVIRONNIZHAAL CONCENTRATIONS OF TRACE ELEMENTS WITH ECOLOGICAL BENCIPARKS

_	<	-	a/v	9	9/V	=	0/V	E:	A/E		· 1/F	3 5	V/C	=	Ş
_	Estlantei	EPC(A)		Nean		() V [uthu		[,nurst		Threshold		Trapard		Ashicut	
	Punt- Dilution			Texis (b)		Toxic		Ubant veil Toxfe		Moscum- ulation		Freehunter Griteria		(*) (*)	
-	Colic.	•	•	ng/l		Func.		Conevil		1		1/2			,
TRACE ELEVENTS												U		_	
Arsente	2. JE-1	1.05-2	2. JEIJ	3.1	1.48-2	5.26-1	4.48-1	2.2E-2	1.0611	C-30.5	4-6EH	5.76-2		ــــــــــــــــــــــــــــــــــــــ	6.6ELL_
Rery! I tum	1.26-1	1.15-2	1,1541	9.6	1.25-2			1.58-1	-8.0E-1	La LELA	1,,)E=]	1.75-4.	7.JEP2	1.08-5-	L. TEM.
<b>T</b> aron	1.95-1	5,0	1.68-1	4. DEAL	2.01-2					.1.5EHZ.	LL			2, 95-2	.H.U
Cutheline	1.35-1_	4.05-3.	1.JE12	5E=2.L		L	2.6612	1.75-4	.1.6E12_		4.5EIL		-213LL	2.4K=4	5.4EP2_
Conner												•	ĺ		
Fluor Ine	۲.8			EH2				2.3							- U32.E
lron		•			i					]					
l.end -	<u>4. JE-2</u>	2-36	<u> </u>	1.8	2.42-2	J.0E-2		L.		6.02.3	2.2	1.32-2	3.4	14.48-1-	
Hanganuse	2.25-1	-2.0E-2	112111	-1,2EIL	.1 «8E=2	1.6	-2-36.2.	1,56-	<u>6.35-2</u>	ר-זוגנו	1.36.1			1-30.6	1.1
Hercury	2.15-2	3. DFS	-5132.4	2.0F-3	.2.3	1.46-21-1		4.115-5	-2135.2-		1,0812	6.42-5 <sup>h</sup>	3. 1612	-12-10-2	-2120-6
Hickel	3.82-2	-1-30.5-	1136.1	-1-25.6-	1.2E-1.	.J. OE=2		_3.UE-2		.2.0E-2	1.9			J. 16-31.6	1.2511
Selenism				İ		ļ							ļ		
Variad tum	4.5E-3	7.52-2	6.05/2	2.4611	1.98-4			4.8	9.46-4	1-20.0	1.45-2				2.2
Z1 nc			;   	   					Ī						
TOTAL TRACE FLIPHFUITS												;    ;			
ALI PIATICS ALICYCLICS															
Acette Acid															ļ
Butanole Acid						Ì	Ì	Ì				Ì			
lievanole Acid												ļ			
<b>J-Hethylbutanoic Acid</b>					Í							Ì	Ī	Ì	11
2-lictingInrounalc Acid.			ĺ				Ī							Ì	
Pentanole Acid					].	İ		Ì	T			Ì	Ì	Ì	
Propariole Acld							Ì				Ì			Ì	
TOTAL FATTY ACIDS															
AENZENES & SUNSTITUTED															
Diplicing					1			İ						Ì	
Ethylbentens	1		ĺ				Ì						1	Ì	
Indan	1			i	Í					1				Ī	
Toluene	Ì						Ì							Í	
I, 2, 4-Tr indthy bourene					1	Ì	İ							ļ	
u-Xy1 cite							Ï								

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TABLE 3-7 (Concluded)

<sup>c</sup>Concentrations causing 16 percent reproductive impairment after 3 weeks exposure<sup>12</sup> <sup>b</sup>Mean concentration toxic to freshwater crustaceans unless otherwise noted <sup>d</sup>Regardless of species, endpoint, conditions of exposure<sup>49</sup> <sup>a</sup>Estimated permissible concentration for water, ecology  $\frac{34}{di}$ Ģ <sup>e</sup>Reference 106

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fReference 89

&Assumes hardness of water is 50 mg/l as CaCO\_3 209,210,211  $$^{\rm h}_{\rm In}$  h Inorganic mercury

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# TABLE 3-8: REVERSE OSMOSIS WASTE (STREAM 53): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS OF ORGANICS WITH ECOLOGICAL BENCHMARKS

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		····						ન
	- ۸	п	A/8	C	∧/c	ס	٨/٥	ŀ
	Estimated Post- Dilution Conc.	Lowest Observed LC <sub>50</sub>		:Lowest Observed Toxic <sup>b</sup> Conc.	ı. L	EPC <sup>C</sup> WC	ų, s	
TRACE ELEMENTS	_ mg/1	mg/1		mg/1				Ł
Aluminum	ļ						~	
Arsenic							ŝ	1
Beryllium								1
Boron	,							1
Cadmium			•	4				1
Copper			•					1
Fluorine			•					1
Iron							÷	1
Lead	· · ·					1	۰.	1
Мапдалеве				÷.			:	1
Mercury					-	-	÷.	1
Nickel								1
Selenium				·. ·				1
Vanadium								ľ
Zinc					:			1
TOTAL TRACE ELEMENTS								1
ALIPHATICS, ALICYCLICS AND FAITY ACIDS								ŀ
Acetic Acid	3.3	4.7E+1	7.0E-2			5.0E-1	6.6	
Butanoic Acid	3.1E-1	6.1E+1	5.1E-3	2.0E+1	1.6E-2			1
Hexanoic Acid	2.4E-2	2.2E+1	1.1E-3	1.0E-2	2.4	4,4	5.5E-3	
3-Methylbutanoic Acid	2.4E-2							1
2-Methylpropanoic Acid	4.8E-2			3.5E+2	5.5E-4			1
Pentanoic Acid	2.8E-1	7.7E+1	3.6E-3			j 3 <b>.</b> 9	7.3E-2	1
Propanoic Acid	6.3E-1,	5.0E+1	1.3E-2					1
TOTAL FATTY ACIDS			·					]
BENZENES & SUBSTITUTED						,		
Bipheny1	1.6E-1						:	Ì
Ethylbenzene	7.3E-1	3.2E+1	2.3E-2			2.5E-1	2.9	1
Indan	2.0 .					4.0E-1	2.9	1
Toluene	2.4	9.5	2.5E-1	3.1	7.7E-1	2.56+1	9.6	1
1,2,4-Trimethylbenzene								1
o-Xylene	8.3E-1			5.0	1.7E-1	5.0E-1	1.7	1
								-

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# //TABLE 3-8 (continued)

	<u>\$2</u>							
≬[		// <b>N</b>	В	۸/B	r c	۸/c	ŋ	A/D
		Entimated	Lowest		Lowest	i,	EPC C	
		Dilution	LC a		Observed Toxic b		=	4
		"/ Conc.	50		Conc.		mg/l	
-	PHENOLS	, mg/1	mg/1.	· · · · · · · · · · · · · · · · · · ·	mg/1			
Ĵ	Catechol	4.4	1.46+1	3.1E-1	3.0	1.5	3-0E-1	4.48+1
Ĩ	3.6-Dimethylcatechol	3.6E-1			=			
Γ	3-Nethylcatechol							
ſ	4-Mechylcatechol	3.1			7.0E+1	4.4E-2		
	2-Methylphenol	3.3E-2	5.0	6.6E-3	2.0	1.76-2	5.0E-2 <sup>d</sup>	6.6E-1
	J-Methylphenol	4.8E-2	1.9E+1	2.5E-3	7.0	6.9E-3	5.0E-2 <sup>d</sup>	9.6E-1
	4-Methylphenol	3.0E-2	1.4	2.1Ė-2			5.0E-2 <sup>d</sup>	6.0E-1
	4-Methylresorcinol	2.8E-1						
	5-Methylresorcinol	S.3E-1						
	Phenol	9.6E-2	1.4	6.9E-2	1.0E-2	9.6	5.0E-1	1.9E-2
	Resorcinol	11.5	8.0E-1	1.9			1.0E-1	1.5E+1
ļ	2,4-Xylenol	9.1E-2	1.3E+1	7.0E-3			_1.0e	9.1E-2
ŀ	'3,5-Xylenol	<u>11.'3E-1</u>	5.0E+1	2.6E-3	1.6E+1	8.1E-3	₹.0 <sup>e</sup>	1.3E-1
	TOTAL PHENOLS	10.3					1.0E-1	1.0E+2
ſ	POLYNUCLEAR AROMATIC	1						•
	HYDROCARBONS	i.						
+	Acenaphthalene	3.0E-2						
ŀ	"Anthracene	7.62-3			5.0	1.5E-3		
ł	Benz(a)anthracene	7.61-4			1.0	7.6E-4		
┟	Benzo(g,h,i)perylene	Z.215-5						
╞	Benzo(a)pyrene	3.0E-4	,					
+	Benzo(e)pyrene	3.01-4						
┟	Chrysene	1.5E-4			5.0	3.0E-5	· · · · ·	
╞	Fluoranthene	1.5E-2			_1.0E-1_	1.5E~1		
$\left  \right $	Fluorene	1.5E-2			5.0	3.05-3		,
┟	Naphthalene	7.1E-1	2.4	3.0E-1	1.0E-2	7.0E+1	5.0E-2	1.4E+1
ł	Perylene	3.2E-4	3.0E-5		1.0	3.0E-5		
	Phenanthrene	7.6E-3	1.1	6.9E-3	1.4E-3	5.4E-1		
ł	Pyrene	1.5E-2			1.0E+1	1.5E-3		
ŀ	TOTAL PAH'6		<u>-</u>					
ſ	SULFUR HETEROCYCLICS							
	Methylthiophene		25					<i></i>
[	Thiophene							:
•	TOTAL THIOPHENES							
•	्यं		·,					

# TABLE 3-8 (concluded)

	A	В	A/B	C	A/C	ם	٨/D
	Estimated	Lowest	5	I,owest		EPC c	
	Post-	LC.		Ubserved Toxic b		_	
	Conc.	50 mg/1	·	Conc.	·		2
<i>e</i>	mg/1		5	mg/1		mg/1	
NITROGEN HETEROCYCLICS							
2,4-Dimethylpyridine	6.6E-4						
2,5-Dimethylpyridine	6.6E-4					i	
2-Methylpyridine	4.6E-2					<u> </u>	
3-Methylpyridine	1.7E-1						<u> </u>
4-Methylpyridine	4.1E-1					<b> </b>	·
Pyridine	7.5E-3	6.3E+2	1.2E-5	1.5E+1	5.0E-4	5.0	1.5E-3
Quinoline	6.3E-3	1.0E+1	6.3E-4	3.8	1.7E-3	5.0E-1	1.3E-2
OXYGEN HETEROCYCLICS	-						
Benzofuran		·					
Dibenzofuran	5.6E-3						
MERCAPTANS	· · ·						
Methanethiol	1.5		11	5.0E-1	3.0		
TOTAL MERCAPTANS					ŀ		· .
AROMATIC AMINES							
Aniline	3.3E-3	4.0E-1	8.3E-3	•		5.0E-1	6.6E-3
TOTAL AROMATIC AMINES							
NITROSAMINES	<b></b>	1		1	1	1	1
	ļ		· · ·	·	· · · · · · · · · · · · · · · · · · ·		<u> </u>
MISCELLANEOUS				1	1		
Annonia	<u> </u>				<u> </u>		
Carbonyl Sulfide					<u>``</u>		<u> </u>
Hydrogen Cyanide							;
Hydrogen Sulfide					,	1	
Nickel Carbonyl			÷				
NO <sub>x</sub> "							
Particulates				:			
SOy							
Taxa Odla Nonhtha		1	1			1	

<sup>a</sup>Values are for <u>Daphnia sp</u>. or fish, <sup>2</sup>/<sub>2</sub>4-96 hr/References for individual compounds are given in Ecological <sub>/</sub>Report.

<sup>b</sup>Regardless of species, endpoint or exposure conditions <sup>49</sup>.
<sup>c</sup>Estimated Permissible Concentrations for water and ecology<sup>34,35</sup>.
<sup>d</sup>Value is for total cresols
<sup>e</sup>Value is for total xylenols

# TABLE 3-9

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# UTILITY STACK GAS POLLUTANTS (STREAM 28): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS WITH ECOLOGICAL BENCHMARKS

	A	B	A/B	с	A/C	n	∧/D	E	∧/E
	Estimated	Most		Loyest		EPC		Ambient	
	Pest-	Stringent		Observed		E (		Air	2
	Conc.	(ug/m <sup>3</sup> ) <sup>b</sup>		Conc.		(µg/46)		(ug/m <sup>3</sup> ) <sup>e</sup>	
	(µg/m <sup>3</sup> ) <sup>a</sup>			(µg/m <sup>3</sup> ) <sup>c</sup>			2		
TRACE ELEMENTS							•	•.	
Aluminum			,				•		
Arsenic -	5.8E-4	2	2.9E-4	-		<u>5.0E-3</u>	1.2E-1	<u>1.5E-2</u>	<u>3.9E-2</u>
Beryllium	6.1E-4	2	3.1E-4	3.5E+1	1.7E-5	<u>5.0E-3</u>	1.2E-1	2.0E-4	3.1
Roron									
Cadmium	5.1E-4	4.0E+1	1.3E-5	1.0E+1	5.1E-5	1.2E-1	4.3E-3	_1.0E-3	5.1E-1
Copper "									
Fluorine		. :				·			
Iron				·					·
Lead	6.0E-3	1.5	4.0E-3			3.6E-1	<u>1.1E-1</u>	2.2E-2	2.7E-1
Manganese	-				·				
Mercury	3.9E-2	5.0E+1	7.8E-4	1.0E+1	3.9E-3	1.0E-1	4.0E-1	7.0E-5	· 5.6E+2
Nickel									
Selenium									
Vanadium					<u>_</u>				
Zinc			7	-					
TOTAL TRACE ELEMENTS									
ALIPHATICS; ALICYCLICE		1							
AND FATTY ACIDS	1					· ·			
Acetic Acid	ļ					·		<u></u>	
Butanoic Acid					<u> </u>			· · · · ·	
Hexanoic Acid	· · ·				`	С			
3-Methylbutanoic Acid					·	·			
2-Methylpropanoic Acid									
Pentanoic Acid	<u> </u>								
Propanoic Acid									
TOTAL FATTY ACIDS	ļ			··	·				<u>د</u>
BENZENES & SUBSTITUTED									
BENZENES									
Biphenyl	<u> </u>	<u> </u>						·	
Ethylbenzene	<u> </u>	ļ						<u>د</u>	
Indan									
Toluene	<b>*</b>	ē					_		
1,2,4-Trimethylbenzene	\`	ļ		· · ·	<u>র্</u>			·	
o-Xylene									
\;			•••			v			
---	---	---	-------------	--	----------	--	-----	---	-----
	Λ Estimated Post- Dilution Conc. (μg/m <sup>3</sup> ) <sup>a</sup>	B Most Stringent Criteria (µg/m <sup>-)</sup> b	А/В	C Lowest Observed Toxic Conc <sub>3</sub> (ug/m) <sup>c</sup>	A/C	D EPC <sub>E</sub> (ug/m <sup>3</sup> ) <sup>d</sup>	A/D	E Ambient Air Conç. (ug/m) <sup>e</sup>	∧/E
PHENOLS									
Catechol		•,			]				
3,6-Dimethylcatechol							,	•	
3-Methylcatechol			- <u></u> _					:	
4-Methylcatechol						·			
2-Methylphenol		<u>.</u>							
3-Methýlphenol									
4-Methylphenol		[]				•			
4-Methylresorcinol					•				
5-Methylresorcinol									
Phenol.					;				42
Resorcinol					•		· .		
2,4-Xylenol		0						· ·	
3,5-Xylenol				• • •					
TOTAL PHENOLS		Ţ							
FOLYNUCLEAR AROMATIC									
Acenaphthalene		1,			1				
Anthracene	· ·								
Benz(a)anthracene 👉		· · · ·							
Benzo(g,h,i)perylene		\						:.	
Benzo(a)pyrene		·	•	·					
Benzo(e)pyrene	-								•
Chrysene									:
Fluoranthene									
Fluorene									
Naphthalene									
Perylene					· · ·				
Phenanthrene									
Fyrene							1		
TOTAL PAH's									
SULFUR HETEROCYCLICS Methylthiophene									
Thiophene :	L			L	ľ	ļ	ļ		
TOTAL THIOPHENES					<u> </u>				

TABLE 3-9(Continued)

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: TABLE 3-9(Continued)

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<u> </u>	Δ	В	A/B	с	۸/C	D	A/D	E	∧/E
、	Estimated Post- Dilution Conc <sub>3</sub> (Ug/m <sup>3</sup> ) <sup>a</sup>	Most Stringent Criteria (µg/m <sup>3</sup> ) <sup>6</sup>		Lowest Observed Toxic Conc. (µg/m3)c		EPC E (µg/m3) <sup>d</sup>	•	Ambient Air .Conc. (µg/m <sup>3</sup> ) <sup>e</sup>	••
NITROGEN HETEROCYCLICS	.1F64.94_4-			 		· · ·			
2,4-Dimethylpyridine									
2,5-Dimethylpyridine			1		<u>'</u>				
2-Methylpyridine						i			
3-Methylpyridine		•							
4-Methylpyridine			<u>`</u>						
Pyridine								•	
Quinoline									
OXYGEN NETEROCYCLICS Benzofuran		:		<u>.</u>			·	·	
Dibenzofuran				2					
MERCAPTANS									•
Methanethiol						X			
TOTAL MERCAPIANS									
AROMATIC AMINES									
Aniline									
TOTAL ARONATIC AMINES					·				_
NITROSAMINES		jt.							
MISCELLANEOUS									
Ammonia									
Carbonyl Sulfide									
Nydrogen Cyanide								;	
Hydrogen Sulfide						ļ		<u>''</u>	
Nickel Carbonyl		1.5E+?				1.0E-1	·	9.0E-2	
NOX	1.3E+2	1.0E+2	1.3	4.4E+2	3.0E-1	<u> </u>			
Particulates	2.0	60	3.3E-2	·					
so <sub>x</sub>	7.0E+2	8.0E+1	8.8	8.6E+1	8.1				
Tars, Oils, Naphrha	i .								

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## TABLE 3-9 (Concluded)

<sup>a</sup>Based on dilution factors derived from SAM/1 model no data were available for many other pollutants<sub>2</sub>likely to be present such as selenium, boron, fluorine, manganese or vanadium
 <sup>b</sup>National Primary and Secondary Ambient Air Quality Standards <u>OR</u> NIOSH<sup>80</sup>

<sup>C</sup>Lowest toxic concentrations regardless of species, response, exposure conditions<sup>35</sup>

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<sup>d</sup>Estimated permissible concentrations in air for ecology<sup>35</sup>

<sup>e</sup>Median concentrations for USA<sup>17</sup>, 190

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ground-level concentrations have been obtained for several constituents of this waste stream. Ratios of maximum ground level concentrations to toxicologic benchmarks result in the classification of mercury, arsenic, beryllium, and lead as Possible Hazards. Other trace elements such as boron, barium, cobalt, chromium, copper, fluorine, manganese, selenium, tin, uranium, vanadium and zinc are likely to occur in stack gases; existing information however, was inadequate for quantifying emission rates for these elements.

The estimated maximum ground level concentration of sulfur oxides is almost nine times the National Secondary Ambient Air Quality. Standard; consequently sulfur oxides are placed in the Possible Hazard category. Nitrogen oxides also are Possible Hazards, because their maximum ground level concentrations also exceed the National Ambient Air Quality Standard.

Table 3-10 presents the results of an attempt to estimate soil deposition flux of several trace elements from stack gas emission rates. Using a model-generated relationship between emission rates and maximum deposition flux for a site near St. Louis<sup>213</sup>, deposition rates have been calculated for a hypothetical liquefaction plant with a stack 300 meters in height. As shown by Table 3-10, with the exception of mercury the annual maximum deposition of each metal' from the hypothetical plant represents a small percentage of the total natural flux from rock weathering, rain, and dust fallout of that metal to an "average" uncontaminated and uncultivated soil. Even if 100% rather than 6% deposition of trace elements within 50 km of the site had been assumed, project-related deposition of the metals would have been a relatively small fraction of natural metal flux, except for mercury. In view of the considerable toxicity of mercury compounds as well as the magnitude of releases potential estimated from indirect coal liquefaction, emissions of mercury should be considered a potential ecological threat deserving the highest research priority.

TABLE 3-10 STREAM 28 (UTILITY STACK GASES): IMPACTS OF TRACE ELEMENTS ON SOILS.

			_					~		ŀ
3		2.25-6		2.05-0	2.2E-4	1.56-5	<b>J.1E-2</b>		45-4	
2	. 1 0	1.3E-7	, 1	1.28-/	1.3E5	98-7	1.85-3		2.4E-5	
۷	도 [1]보	2.1E-3		!	1.9E-2	7.4E-3	1-36-1		1.5E-L	
•	20 21	1.36-4		-	1.1E-3	4.5E-4	1.05 0		9.2E-3	
-	Mean Sot1 Conc.f μg/g	6E 0		6E 0	6E-2	1+30.1	1E-7	1	4.0E+1	
Ξ	Natural Flux to Sgll <sup>e</sup> µg/m <sup>2</sup> /yr	1.4E		1	1,6641	4.76+2	0 26 1	1.76 0	2.58+4	
9	Worst- Game Change in Annual Soil Conc.d µg/g	+1 . 3E-5		+1.5E-5	+1.3E-5	+1_5E-4	7 36 01	T7.25-4	+1.6E-2	
<u>بط</u>	Worst- Case Haximum Deposition After 40 yrs <sup>d</sup> 42 w2	1 2641		1.4E+1	1.25+1	1 464.9		0./E+2	1.5E+4	
21	Worst- Case Naximum Pelosition Pluxd Pluxd	36.1	1-32	3.7E-1	1-36	0 45 5		Z.ZE+1	3.8E+2	
٥	Change in Annual Soil Conc.c μg/g	1.7 EF 7	1-30.14	49.2E~7	47 5R-7	9-20 01		+5.5E-5	+9.5E-4	
0	Haximum Deposition After 40 yrs. μg/m <sup>2</sup>	-	1.25-1	8.6E-1	7 25-1	4 44 9	0 71.0	5.2E+1	9.1E+2	
ff	Maximum Jeposition Flux <sup>b</sup> µg/m <sup>2</sup> /yr		1.8E-2	2.2E-2	1 00.0	1.00-6	<u></u>	1.3E 0	2.3E+1	
<	: Emission Rate <sup>a</sup> mg/g		8.8E-Z	1.06-1		0.00-2	<u>0 30.1</u>	6.3E 0	8.9E+1	
	elements .		Arsenic	Bowillium	10777430	Cadmin	Lead	Mercury	, 1919 N	INTERNET.

<sup>a</sup> Based on: stream characterization data for conceptual reference facility (See Volume II)

and deposition from 300-m 313 stack of hypothetical 1400-MWe plant sited near St. Louis, assuming 6% deposition within 50 km of plant. <sup>b</sup>Estimated by using Battelle study model which calculates trace element transport

c<sub>Annual</sub> increase in soll concentration from conceptual coal conversion deposition assuming no soil output; <sup>1</sup>Ratio of annual project-induced sol' concentration increase to mean endogenous soil concentration.<sup>213</sup> ŀ  $^{
m h}$ Ratio of worst-case annual project related deposition to natural annual flux to soil. $^{17-1}$  $^{e}$ Annual input to uncontaminated, uncultivated soil from rock weathering, rain, and dust  $^{17}$  $^{
m g}$ Ratio of maximum annual project-related deposition to natural annual flux to soil  $^{
m 17}$ assumes soil density = 1.2 g/cm<sup>3</sup>, retention of trace elements in top 2 cm of soil. d<sub>As</sub> (a) above, but assumes 100% rather than 6% deposition within 50 km of plant. 213 Emean endogenous soil concentration.

. <sup>213</sup> Ratio of annual worst-case project-induced soil concentration increase to mean endogenous soil concentration.

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<u>Cooling Tower Atmospheric Losses</u>: (Stream 29) - Table 3-11 lists the estimated emission rates for several contaminants expected to occur in the cooling tower evaporative losses and drift. Other trace elements and compounds, some potentially harmful, may be released by this stream, but existing information is insufficient for even a rough estimate of their emission rates.

Estimated ambient concentrations for the constituents of this stream could not be derived for the ecological analysis because partitioning of the contaminants between the vapor phase and liquid droplet phase could not be determined, and it was expected that such partitioning would lead to substantially different contaminant concentrations in the two phases.

Although contaminants from this waste stream are not categorized, a qualitative assessment has been developed. Based on such physical characteristics as solubilities and vapor pressure, the trace elements and polynuclear aromatic hydrocarbons might be expected to dominate the drift, while phenols and low-molecular weight, heterocyclic, nitrogensubstituted compounds (pyridines) may favor the vapor phase.

Partitioning of contaminants between the two phases is important because the drift (droplet) phase will settle to the ground over a much more limited area relatively close to the plant than will the vapor phase. Thus, whatever contaminants are present in the drift phase will tend to become enriched on the surface of vegetation and in soils within one or two kilometers of the plant. Over the life of the plant, salts, metals, and the more persistent polynuclear aromatic hydrocarbons may reach concentrations in the soil deleterious to soil communities, vegetation, and animals.

On the basis of relative release rates, the presence of substantial levels of organics, the problem of drift, and the uncertainties related to potential ambient environmental concentrations, Stream 29 appears to represent the most important short-term threat (among atmospheric emissions) to local terrestrial and aquatic ecosystems, although stack gases may represent a more important regional stress.

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## TABLE 3-11 .

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COOLING TOWER EVAPORATIVE LOSSES AND DRIFT (STREAM 29) ESTIMATED EMISSION RATES OF EXPECTED CONTAMINANTS

Compound/Trace Elements	Emission Rate mg/s	Compound/Trace Elements	Emission Rate mg/s
Arsenic	5.5	3,5-Xylenol	2.8
Beryllium	2.6	3,6-Dimethyl catechol	24
Cadmium	3.0	4-Methyl resorcinol	19
Fluorine	120	4-Methylcatechol	200
 Lead	5.8	4-Methylphenol	2.0
Mercury	0.46	4-Methylpyridine	0.27
Nickel	0.15	5-Methylresorcinol	33
Vanadium	0.046	Acenaphthylene	0.061
Ammonia	7,600	Anthracene	0.015
Aceric acid	640	Benz(a)anthracene	0.0015
Aniline	0.40	Benz(a)pyrene	$6.1 \times 10^{-4}$
Butanoic acid	36	Benzo(e)pyrene	$6.1 \times 10^{-4}$
Catechol	290	Benzo(g,h,i)perylene	$6.1 \times 10^{-5}$
Hexanoic acid	2.8	Biphenyl	0.30
 Pentanoic acid	33	Chrysene	$3.0 \times 10^{-4}$
Phenol	8.5	Dibenzofuran	0-40
Propanoic acid	67	Ethylbenzene	85
Pyridine	0.55	Fluoranthene	0.030
Resorcinol	97	Indan	4.0
2-Methylphenol	2.3	Methanethiol	33
2-Methylpropionic acid	5.5	Naphthalene	1_4
2-Methylpyridine	3.3	Perylene	6.1x10 <sup>-5</sup>
2,4-Dimethylpyridine	0.046	Phenanthrene	0.015
2,4-Xylenol	2.0	Pyrene	.0.030
2,5-Dimethylpyridine	0.046	Quinoline	0.43
3-Methylbutanoic acid	2.8	Toluene	280
3-Methylphenol	1.4	o-Xylene	97
3-Methylpyridine	1.2	, ·**	

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<u>Coal Lockhopper Vent Gas</u>: (Stream 72) - The overall emission rate for the coal lockhopper vent gas is relatively low. With the exception of "gas's, very little information is available on the individual of constituents of this waste stream. There also is a paucity of data on the coxicological effects of gaseous pollutants on ecosystems with the exception of some of the Federally-regulated emissions. Therefore, much of the information on coal lockhopper vent gases has been assessed based upon standards and criteria for classes of compounds rather than individual compounds. Similarly, in some cases the toxic concentrations for a class of compounds is based upon the toxic concentrations of a single chemical member of that class.

Of the constituents that have been evaluated, none are identified as Probable Hazards (see Table 3-12). Only the phenols were identified as a Possible Hazard. However, tars, oils and naphthas are emitted in relatively high rates and are expected to contain polycyclic aromatic hydrocarbons, phenolic derivatives, and aliphatic hydrocarbons. The implications for the health of local ecosystems are unknown for these contaminunts.

3.4 DISCUSSION

The operation of an indirect liquefaction facility may affect surrounding aquatic and terrestrial biological communities. In general the aqueous effluents and leachates represented the greatest potential threats to aquatic ecosystems and atmospheric emissions represent the most likely candidates for affecting terrestrial biota. Of course leachate, if toxic, may also affect terrestrial soil communities and the vegetation that they support. Similarly, atmospheric emissions may be deposited in surface waters, thus adding to the total aquatic pollutant load. Based upon the results of the ecological assessment, the waste streams and toxic substances that appear to be of the greatest ecological concern are described in the following sections.

TABLE 3-12: LOCKHOPPER VENT GAS EMISSIONS (STREAM 72): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRA-TIONS WITH ECOLOGICAL BENCHMARKS

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······································	A ·	R I	A/1
м., ,	Estimated Post- Dilution Conc. (ug/m <sup>3</sup> ) <sup>a</sup>	Toxic <sup>b</sup> Conc. (μg/m <sup>3</sup> )	A/ D
TRACE ELEMENTS			
Aluminum	ļ		
Arsenic	ļ		
Bervllium		<u> </u>	
Boron		[···	
Caùmium	<u> </u>	-	
Copper			
Fluorine		}	
lron		:	
Lead	<u> </u>		
Manganese	l		
Mercury	1	ņ.	
Nickel	J		
Selenium		1	
Vanadium	1		
Zinc		1	
TOTAL TRACE ELEMENTS	2.5E-2	5.0E-1ª	5.0E-2
ALIPHATICS, ALICYCLICS AND FATTY ACIDS			
Acetic Acid	[·		
Butanoic Acid	<u> </u>		
Hezanoic Acid	<u> </u>		
3-Methylbutanoic Acid			
2-Methylpropanoic Acid			
Fentanoic Acid		I	
Propanoic Acid			
TOTAL FATTY ACIDS	<u>  Ì.3C+1</u>	2.0E+6	6.5E-6
BENZENES & SUBSTITUTED			
Biphenvl			
Ethylbenzene			
Indan			
Toluene			
1,2,4-Trimethvlhenzene	<u> </u>		
o-Xvlene			

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TABLE 3-12 (continued) .

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	j. J	A Estimated Post-Dilu	B Toxic Conc.	A/Bʻ.	
	<u> </u>	tion Conc. (µg/m <sup>3</sup> ) <sup>a</sup>	(µg/m <sup>3</sup> )	· · ·	
	PHENOLS			•	
	Catechol				
1	3.6-Dimethvlcatechol				
	3-Methylcatechol				
	4-Methvlcatechol			,·	
	2-Methylphenol			· ·	
	3-Methvlphenol			i	
	4-Methvlphenol	l		6	
	4-Methvlresorcinol		<u>-</u>		
	<u>&gt; 5-Methvlresorcinol</u>			<u> </u>	
	Phenol			<u> </u>	
	Resorcinol				
	2.4-Xvlenol	· · · · ·			Ľ
	3,5-Xvlenol			·.	
	TOTAL PHENOLS	6.4E+1	1.0E+2	6.4E-1	
	POLYNUCLEAR AROMATIC HYDROCARBONS			· .	
	Acenaphthalene	<u> </u>		1	
	Anthracene			1	
	Benz(a)anthracene		:		b
	Benzo(g,h,i)pervlene			!	
	: Benzo(a)pyrene		L		
	Benzo(e)ovrene			!	
	Chrysene			I	
	Fluoranthene		-		
	Fluorene				Į
	Naphthalene			:	
	Perviene			i	
	Phenanthrene		_		
	Pyrene	1			
	TOTAL PAH's	2.4E-2	7.9E+4	3.0E-7	
	SULFUR HETEROCYCLICS				i.
	Methylthiophene	<u> </u>		ļ	
	Thiophene			ļ	
	TOTAL THIOPHENES	2.0E-1	3.0E+7	6.7E-9	l

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## TABLE 3-12 (continued) :

E         F         F         F         C         C         NITROGEN HETEROCYCLICS         2,4-Dimethylpyridine         2,5-Dimethylpyridine         3-Methylpyridine         3-Methylpyridine         3-Methylpyridine         0uinoline         Ouinoline         OXYGEN HETEROCYCLICS         Benzofuran         Dibenzofuran         MERCAPTANS         Methanethiol         TOTAL MERCAPTANS         ANOMATIC AMINES         NITROSAMINES         MISCELLANEOUS	Estimated Post- Dilution Conc3 up/m <sup>3</sup> )	Toxic <sup>b</sup> Conc. (µg/m <sup>3</sup> )	<u> </u>
I CONTROGEN HETEROCYCLICS 2,4-Dimethylpyridine 2,5-Dimethylpyridine 3-Methylpyridine 3-Methylpyridine 4-Methylpyridine Ouinoline Ouinoline OXYGEN HETEROCYCLICS Benzofuran Dibenzofuran Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	(µg/m <sup>3</sup> )	<u>1.3E-8</u>
NITROGEN HETEROCYCLICS 2,4-Dimethylpyridine 2,5-Dimethylpyridine 3-Methylpyridine 4-Methylpyridine Pyridine Ouinoline OXYGEN HETEROCYCLICS Benzofuran Dibenzofuran Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	: : : : : : : : : : : : : : : : : : :	1.3E-1
2,4-Dimethylpyridine 2,5-Dimethylpyridine 2-Methylpyridine 3-Methylpyridine 4-Methylpyridine Pyridine Ouinoline OXYGEN HETEROCYCLICS Benzofuran Dibenzofuran Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	: : : : : : : : : : : : : : : : : : :	<u>1.3E-8</u>
2.5-Dimethylpyridine 2-Methylpyridine 3-Methylpyridine 4-Methylpyridine Pyridine Ouinoline OXYGEN HETEROCYCLICS Benzofuran Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	: : : : : : : : : : : : : :	1.3E-1
2-Methylpyridine 3-Methylpyridine 4-Methylpyridine Pyridine Ouinoline OXYGEN HETEROCYCLICS Benzofuran Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	2.0E+7	1.3E-1
3-Methylpyridine 4-Methylpyridine Pyridine Ouinoline OXIGEN HETEROCYCLICS Benzofuran Dibenzofurar MERCAPTANS Methamethiol TOTAL MERCAPTANS AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	2.0E+7	1.3E-1
4-Hethylovridine         Pvridine         Ouinoline         OXYGEN HETEROCYCLICS         Benzofuran         Dibenzofurar.         MERCAPTANS         Methamethiol         TOTAL MERCAPTANS         AROMATIC AMINES         NITROSAMINES         MISCELLANEOUS	2.5E-1	: 2.0E+7	1.3E-1
Pyridine         Ouinoline         OXYGEN HETEROCYCLICS         Benzofuran         Dibenzofuran         MERCAPTANS         Methanethiol         TOTAL MERCAPTANS         AROMATIC AMINES         Aniline         TOTAL AROMATIC AMINES         NITROSAMINES         MISCELLANEOUS	2.5E-1	2.0E+7	1.3E-1
Ouinoline       OXYGEN HETEROCYCLICS       Benzofuran       Dibenzofurat       MERCAPTANS       Methanethiol       TOTAL MERCAPTANS       AROMATIC AMINES       Aniline       TOTAL AROMATIC AMINES       NITROSAMINES       MISCELLANEOUS	2.5E-1	2.0E+7	<u> </u>     <u>1.36-</u> 1
OXYGEN HETEROCYCLICS       Benzofuran       Dibenzofurat       MERCAPTANS       Methanethiol       TOTAL MERCAPTANS       AROMATIC AMINES       Aniline       TOTAL AROMATIC AMINES       NITROSAMINES       MISCELLANEOUS	2,5E-1	2.0E+7	1.3E-1
Benzofuran Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	2.0E+7	1.36-
Dibenzofuran MERCAPTANS Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS	2.5E-1	2.0E+7	<u>1.3E-1</u>
MERCAPTANS       Methanethiol       TOTAL MERCAPTANS       AROMATIC AMINES       Aniline       TOTAL AROMATIC AMINES       NITROSAMINES       MISCELLANEOUS	2.5E-1	2.0E+7	<u>1.3E-</u>
Methanethiol TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES HISCELLANEOUS	2.5E-1	2.0E+7	<u>1.36</u> -
TOTAL MERCAPTANS AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES HISCELLANEOUS	2.5E-1	2.0E+7	1.3E-
AROMATIC AMINES Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS		]	
Aniline TOTAL AROMATIC AMINES NITROSAMINES MISCELLANEOUS		1	
TOTAL AROMATIC AMINES			
MITROSAMINES	4.8E-2	4.4+5	1.1E-
HISCELLANEOUS	2.4E-2	4.8E+4	5.0E-7
			]
Armonia .	1.0E+2	1.0E+3	9.9E-2
Carbonvl Sulfide	1.4	7.1E+6	1 2.0E-7
Hydrogen Cyanide	9.6E-2	4.4E+1	1 2.2E-3
Hvårogen Sulfide	6.6E+1	2.8E+4	i 2.4E-3
Nickel Carbonvl	7.2E-2	!	
NC <sub>22</sub>			1
Particulates			1
50 <sub>32</sub>		1	!
Tars, Oils, Bachtha	7.1E+2	!	ļ

<sup>a</sup>Based on dilution factor of 24,000 derived from SAM/1 model<sup>221</sup>.

<sup>b</sup>Published toxicities regardless of species, endpoint, and exposure conditions. In case of classes (e.g., PAH's) toxicities are for specific compounds (e.g., naphthalene)<sup>35</sup>, 36, 130, 215.

<sup>c</sup>Value is for Vanadium<sup>34</sup>.

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## 3.4.1 Aquatic Ecosystems

In the present analysis ash leachates, biosludge, and concentrated waste solution from the reverse osmosis unit are assumed to release contaminants to the aquatic environment. Trace metals and phenols appeared to present the greatest overall concern to the aquatic environment from the waste streams analyzed; although, benzenes and substituted benzenes, polynuclear aromatic hydrocarbons, and possibly nitrogen heterocyclics, may also present problems.

Trace elements are anticipated to be released by all three waste Arsenic, beryllium, cadmium, and mercury are identified as streams. Probable Hazards An more than one waste stream. Post-dilution concentrations of arsenic, cadmium, lead, manganese, and mercury may exceed threshold bioaccumulation concentrations by an order of magnitude. This suggests that these metals may pose a serious threat to public health foods are consumed by the public. These elements in the aqueous waste streams, however, are just part of the overall trace Trace elements in the stack gas and cooling tower element problem. drift may add to the total environmental loading of trace elements. Benzenes and substituted benzenes, and phenols are associated primarily with the reverse osmosis unit waste.

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Polynuclear aromatic hydrocarbons are expected to be present in the reverse osmosis wastes and biosludge, but very little information is available to assess the potential toxicity of the individual compounds suspected to be present. Similarly, little is known about the potential toxicity of nitrogen heterocyclic hydrocarbons that also are expected to be in the reverse osmosis unit waste. These classes of compounds should be considered potential problems until further research has been conducted.

Ash leachate from the conceptual Lurgi/Fischer-Tropsch indirect liquefaction facility using Wyoming subbituminous coal is not expected to pose insurmountable ecological problems, but attention should be given to careful design, lining and operation of ash disposal

facilities. Biosludge appears to be a hazardous waste requiring either gasification or effective containment in well-designed and operated disposal facilities. The reverse osmosis unit waste poses the greatest hazard to aquatic ecosystems due to: 1) the number of potentially hazardous materials in the waste, 2) the relatively high concentration of trace elements and organics, and 3) the relatively high flow rate of this stream. Furthermore, the organic constituents of this stream, if discharged to surface waters, may cause oxygen depletion, which in turn may increase the toxicity of many substances to aquatic organisms.

3.4.2 Terrestrial Ecosystems

The utility stack gas, cooling tower atmospheric losses, and lockhopper vent gas have been identified as the major sources of emissions that could potentially effect terrestrial ecosystems. Possible Hazards include trace elements, gaseous sulfur compounds, nitrogen oxides, fatty acids, phenols, mercaptans, ammonia, nickel carbonyl and nitrosamines.

In the case of atmospheric emissions, Stream 29, the evaporation losses and cooling tower drift, may pose the greatest hazards to terrestrial ecosystems. This is due to the quantities of both organic and inorganic contaminants released, and to the fact that the mode of release is in the form of both drift and vapor. Unfortunately, without knowing how the constituents of this stream will partition between the liquid and vapor phases, no quantitative estimates of pollutant concentrations can be derived.

Next in order of apparent ecological hazard is Stream 28 (utility stack gases) which produces levels of sulfur oxides and nitrogen oxides, that exceed National Ambient Air Quality criteria. In addition to these constituents, arsenic, beryllium, lead and mercury are Possible Hazards. Furthermore, an assessment of the impact of trace elements on soil systems has indicated that mercury contamination from stack gases is a potentially serious problem. Given the considerable toxicity of mercury compounds and the magnitude of estimated releases from an

indirect liquefaction facility, mercury should be considered a Probable, rather than Possible Hazards.

The lockhopper vent gases (Stream 72) are expected to release relatively large quantities of tars, oils, and naphtha; they are present in concentrations that exceed three times the National Primary Ambient Air Quality Standards for non-methane hydrocarbons (160  $ug/m^3$ ). Emissions of trace elements and organics in Stream 72 are lower than those for other streams. The major impact of this stream is as a contributor to the overall pollutant loading in the vicinity of the plant.

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