4 PUBLIC HEALTH ASSESSMENT

4.1 INTRODUCTION

Process and discharge streams from a Lurgi/Fischer-Tropsch facility contain constituents which are known or suspected of being hazardous to human health. These streams also contain constituents for which health effects are unknown.

Development and deployment of indirect liquefaction technology in an environmentally acceptable manner requires that the risks to public health be assessed and reduced to acceptable levels.

This chapter summarizes the assessment of hazards to public health posed by streams which would be discharged by the conceptual reference facility under steady-state operating conditions. Non-steady-state conditions (e.g., spills, explosions, fires) or leaks from internal process streams are not discussed.

Although a sophisticated, quantitative analysis is desirable, it was not feasible due to insufficient data regarding the types and concentrations of pollutants produced by the processes, and uncertainty regarding the biological effects and potential interactions of the pollutants. Instead, the public health assessment is based upon the calculation of body burdens resulting from exposures to selected process streams constituents, and comparisons of estimated, post-dilution, pollutant concentrations to acceptable or recommended human exposure levels such as National Ambient Air Quality Standards (NAAQS), Safe Drinking Water Act Standards (SDWAS), and Estimated Permissible Concentrations for Health (EPC_H).

For a full discussion of the human health assessment the reader is refered to Volume IV of this report. . Many assumptions, caveats, and data used in the analysis are presented in that volume and will not be repeated in this chapter.

4.2 METHODOLOGY

Assessment of risks to public health was accomplished using a tiered methodology, illustrated in Figure 4-1. As shown in the Figure, the first step was the identification of facility streams which may be released to the environment. Evaluation of the conceptual facility indicated twenty streams likely to have environmental releases during normal facility operation (Table 4-1). The chemical constituents of these streams then were identified, based on the results of the stream characterizaton study (described in more detail in Volume II). These chemical constituents are listed in Table 4-2. The chemical constituents were then separated into several categories depending upon the state-of-knowledge regarding their toxicity and stream concentrations. Categorization of the stream constituents facilitated the assessment by allowing the application of quantitative methods when sufficient quantitative data were available and qualitative methods when they were not. The categories also provided an indication of the levels of uncertainty associated with the conclusions regarding the various stream constituents.

Categorization of stream constituents based on the availability of toxicity and stream concentration data was accomplished in two steps. First the constituents were separated into three categories, based on toxicological information:

- constituents known or suspected to be toxic
- constituents of unknown toxicity
- constituents known to be non-toxic

In the second step, constituents that were known or suspected to be toxic were divided into three categories, based on the source and availability of stream concentration data:

- Category A - constituents which have been characterized in streams of commercial-scale Lurgi/Fischer-Tropsch plants identical to the conceptual reference facility presented in Chapter 2. Such empirical data would be an ideal data base for the assessment. Unfortunately this category is empty because no commercial-scale plants identical to the reference facility exist (see Table 4-3).

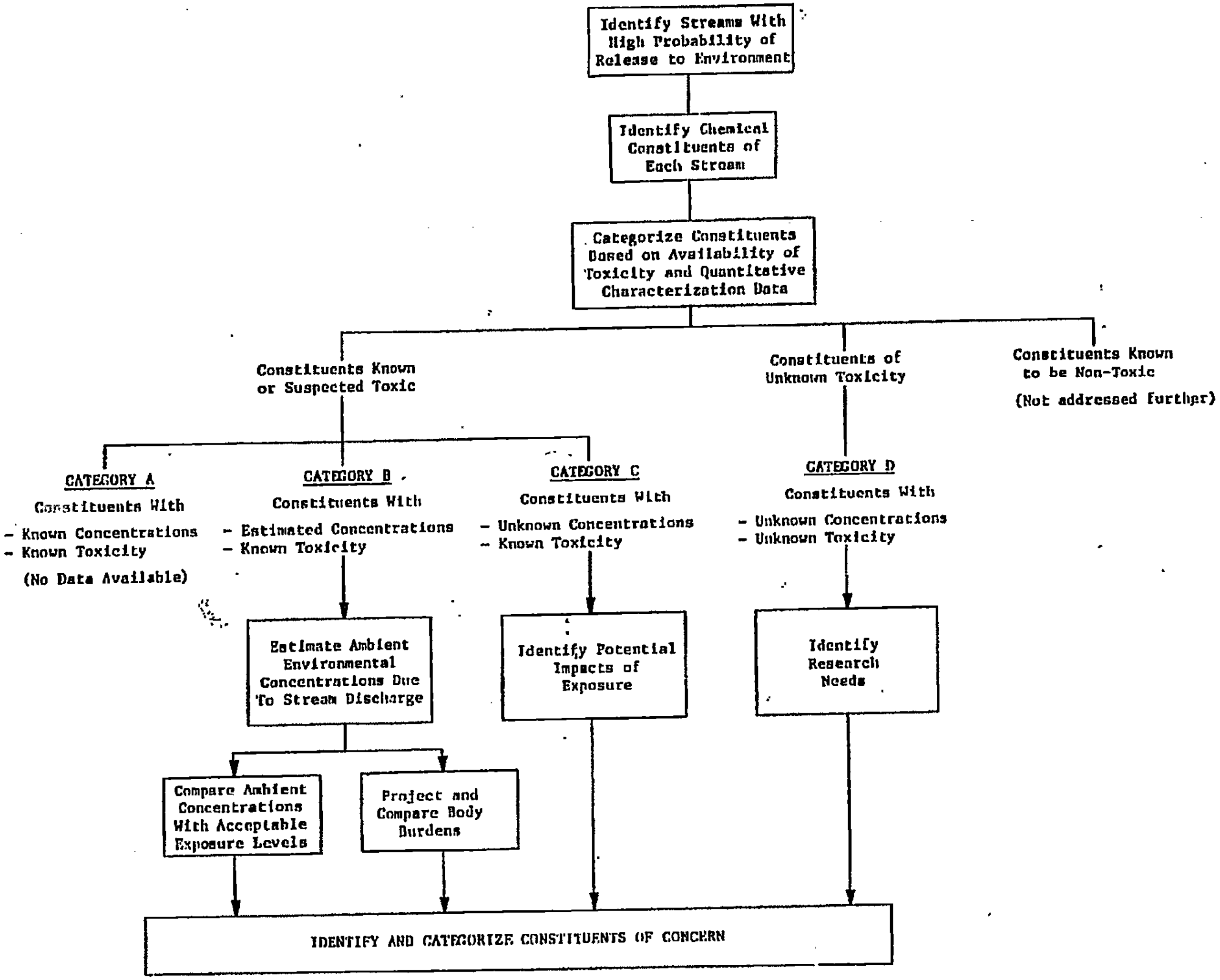


FIGURE 4-1

MAJOR STEPS IN THE PUBLIC HEALTH RISK ASSESSMENT

TABLE 4-1

PLANT STREAMS WITH A HIGH PROBABILITY OF RELEASE TO THE ENVIRONMENT

Gaseous	Process Stream Number*
Bag House Vent Gas	26
Utility Stack Gas	28**
Cooling Tower Atmospheric Losses	29**
Deaeration Emissions	30
Ash Handling Emissions	35
Fischer-Tropsch Purge Gas, Waste Streams	65,67
Lockhopper Vent Gas	72**
Evaporative Losses From Product and Byproduct Streams	73,74,75,76,77
Liquid	
Reverse Osmosis Waste Solution	53**
Utility and Gasified Ash Leachate	69**
Biosludge Leachate	71
Solid	
Combined Utility, Gasifier Ash	36
Spent Fischer-Tropsch Catalyst	63
Biosludge	70
Spent Shift Catalyst	79

* Process stream numbers refer to the block figure diagram for the conceptual plant (Figure 2-1).

TABLE 4-2

CONSTITUENTS OF PROCESS STREAMS LIKELY TO BE RELEASED TO THE ENVIRONMENT

Aliphatics/Alicyclics/ Fatty Acids	Source Streams	Sulfur Heterocyclics	Source
Streams			
Acetic Acid	29,72,53	Methylthiophene	72
Propanoic Acid	29,72,53	Thiophene	72,75
Butanoic Acid	29,72,53	Benzothiophene	75
2-Methylpropanoic Acid	29,72,53		
Pentanoic Acid	29,72,53	Nitrogen Heterocyclics	
3-Methylbutanoic Acid	29,72,53	Acridine	72
Hexanoic Acid	29,72,53	2,4-Dimethylpyridine	29,53
Ethane	72	2,5-Dimethylpyridine	29,53
C_2-C_6 Aliphatics	72	2-Methylpyridine	29,53
Ethanol	74	3-Methylpyridine	29,53
C_3+ Alcohols	74	4-Methylpyridine	29,53
Methane	72	Pyridine	29,53
		Quinoline	29,53,72
Benzene & Substit. Benzenes			
Benzene	75,72	Oxygen Heterocyclics	
Biphenyl	29,72		
Ethylbenzene	29,53,72	Benzofuran	72
Indan	29,72	Dibenzofuran	29,53,72,76
Toluene	29,53,75,72		
Xylenes	72,75		
O-Xylene	29,53		
		Nitrosamines	
Monohydric Phenols		Nitrosamine	72
Cresols	76,75,77,72		
Phenol	29,53,72,75,76, 77		
Alkyl Phenols	75	Polynuclear Aromatic Hydrocarbons	
2-Methylphenol	29,53,72		
3-Methylphenol	29,53		
Trimethylphenol	72	Acenaphthylene	29,53,70
O-Isopropylphenol	72	Anthracene	29,70,72,76
Xylenols	77 72	Benz(a)anthracene	29,70
2,4-Xylenol	29,53	Benzo(g,h,i)perylene	29,70
		Benzo(a)pyrene	29,70
Dihyrdic Phenols		Benzo(e)pyrene	29,70
Catechol	29,53,77	Chrysene	29,70,72
Methylcatechol	77	Fluoranthene	29,70,72,76
4-Methylcatechol	29,53	Fluorene	29,70,72,76
3,6-Dimethylcatechol	29	Indene	72
Resorcinol	29,53,77	Naphthalene	29,70,72,75,76
Methylresorcinol	77	Perylene	29,72
5-Methylresorcinol	29,53	Phenanthrene	29,70,72,76
4-Methylresorcinol	29,53	Pyrene	29,70,76,72

TABLE 4-2 (Concluded)

Aromatic Amines	Source Streams	Trace Elements	Source Streams
Aniline	29,53,72	Aluminum	69
Methylaniline	72	Arsenic	72,28,29,53,36, 69,70,72
Dimethylaniline	72		
		Barium	28,72,36
Gases		Beryllium	72,28,29,53,36,70
		Boron	28,72,29,36,53
SO_x as SO_2	28	Cadmium	28,29,36,53,69,70,72
NO_x as NO	28	Carbon	79
Carbon Monoxide	72	Chromium	28,36,72
Carbon Dioxide	28,72	Cobalt	28,36,72,79
Nickel Carbonyl	72	Copper	69,36,72
Hydrogen Cyanide	72	Fluorine	29,36,53,28
Carbonyl Sulfide	72	Iron	69,72
Ammonia	72	Lead	72,28,29,53,36 69,70,79
Hydrogen Sulfide	72		
Particulates	28	Manganese	28,72,36,53,69
N_2 + Inerts	28,72	Mercury	72,28,29,53,36, 69,70,79
O_2	28		
H_2O	28,36,72	Molybdenum	70
H_2	28,72	Nickel	28,72,29,53,36,69
		Selenium	28,72,36,69,79
Mercaptans			
Methanethiol	29,53,72	Silver	72,36
Ethanethiol	72	Sulfur	36,79
		Zinc	36,69,28,72
		Tin	28,72,36
		Uranium	28,72,36
		Vanadium	28,36,72,29,53

TABLE 4-3

CATEGORY A: TOXIC STREAM CONSTITUENTS WHICH HAVE BEEN
QUANTIFIED IN STREAMS FROM A COMMERCIAL SCALE
LURGI/FISCHER-TROPSCH FACILITY IDENTICAL TO
THE CONCEPTUAL PLANT

Unavailable. Empirical characterization data are not available for effluents form a Lurgi/Fischer-Tropsch Plant using the coal and environmental control specified in the conceptual facility.

- Category B - constituents for which stream concentrations have been estimated, based on data from bench or pilot-scale facilities, Lurgi gasifiers, or non-U.S. Lurgi/Fischer-Tropsch facilities (see Table 4-4).
- Category C - constituents identified as toxic and probably present in the streams, but for which stream concentrations are not available (see Table 4-5).
- Category D - constituents identified as probably present in the process stream, but for which neither toxicity information nor concentrations were available (see Table 4-6).

Stream constituents which were known to be non-toxic (from a human health perspective) were assumed to pose insignificant risks to public health and were not considered further in the assessment. (See Table 4-7).

Constituents in Category "B" were the only constituents for which toxicologic data and estimated stream concentration data were available. Efforts to assess quantitatively public health risks therefore were concentrated on this category of constituents. As shown earlier in Figure 4-1, risks posed by Category "B" constituents were evaluated by two separate methods:

1) Pollutant concentrations (post-dilution) due to the discharge of plant streams, were estimated using dilution factors from the Sources Analysis Model I (SAM/I) being developed for the U.S. Environmental Protection Agency.[221] The SAM/I model uses approximate dispersion models to account for the dilution of a discharge concentration to an ambient concentration. Application of the model to atmospheric emissions yields maximum ground level concentrations. Application of the model to aqueous discharges to surface water bodies or land yields maximum ambient concentrations in surface water bodies or groundwater, respectively.

TABLE 4-4

CATEGORY B: TOXIC STREAM CONSTITUENTS ESTIMATED IN LURGI/FISCHER-TROPSCH WASTE STREAMS

SUBSTANCE	SOURCE STREAMS	SUBSTANCE	SOURCE STREAMS
Benzene, Sub. Benzenes		Oxygen Heterocyclics	
Ethylbenzene	29,53	Dibenzofuran	29,53
Biphenyl	29,53		
Toluene	29,53		
O-Xylene	29,53	Mercaptans	
		Ethanethiol	72
Monohydric Phenols		Methanethiol	29,53
Phenol	72,29,53		
2-Methylphenol	29,53	Aromatic Amines	
3-Methylphenol	29,53	Aniline	29,53,72
4-Methylphenol	29,53	Methylaniline	72
2,4-Xylenol	29,53	Dimethylaniline	72
2,5-Xylenol	29,53		
		Nitrosamines	
Dihydric Phenols		Nitrosamine	72
Catechol	29,53		
4-Methylcatechol	29		
3,6-Dimethylcatechol	29,53	Trace Elements	28,36,72
Resorcinol	29,53	Arsenic	28,29,53,36,69,70,79
5-Methylresorcinol	29,53	Beryllium	28,29,36,53,70
4-Methylresorcinol	29,53	Cadmium	28,29,36,53,69,70
		Cobalt	79
Polynuclear Aromatic Hydrocarbons		Fluorine	29,36,53
Acenaphthylene	29,53,70	Lead	28,29,36,53,69,70,79
Anthracene	29,53,70	Mercury	28,29,36,53,69,70,79
Benz(a)anthracene	29,53,70	Nickel	29,36,53,69
Benz(g,h,i)perylene	29,53,70	Selenium	69,79
Benzo(a)pyrene	29,53,70	Vanadium	29,53
Benzo(e)pyrene	29,53,70	Molybdenum	79
Chrysene	29,53,70	Sulfur	36,79
Fluoranthene	29,53,70	Zinc	36,69
Fluorene	29,53,70		
Naphthalene	29,53,70	Gases	
Phenanthrene	29,53,70	SO_x	28
Xylene	29,53,70	NO_x	28
		Carbon Monoxide	28,72
		Nickel Carbonyl	72
Sulfur Heterocyclics		Hydrogen Cyanide	72
Thiophene	72	Carbonyl Sulfide	72
		Ammonia	29,72
Nitrogen Heterocyclics		Hydrogen Sulfide	72
2,4-Dimethylpyridine	29,53		
2,5-Dimethylpyridine	29,53		
2-Methylpyridine	29,53		
3-Methylpyridine	29,53		
4-Methylpyridine	29,53		
Pyridine	29,53		

TABLE 4-5

CATEGORY C: TOXIC STREAM CONSTITUENTS FOR WHICH CONCENTRATIONS ARE NEITHER KNOWN NOR ESTIMATED

Substance	Source Streams	Substance	Source Streams
C_3+ Alcohols	60	Dibenzofuran*	76,72
Benzene	72,75	Barium	28,36,72
Ethylbenzene*	72	Cobalt	28,36,72
Toluene*	72,75	Chromium	28,36,72
Xylene*	72,75	Fluorine*	28,72
Cresols*	72,75,76,77	Nickel*	28,72
Phenol*	72,75,76,77	Selenium*	28,36,72
Alkyl Phenols*	72,75	Vanadium*	28,36,72
2-Methylphenol	72	Zinc	28,72
Trimethylphenol	72	Uranium	28,36,72
O-Isopropylphenol	72	Silver	36,72
Xylenols*	72,77	Acridine	72
Catechol*	77	Biphenyl*	72
Methylcatechol*	77	Chrysene*	72
Resorcinol*	77	Indene	72
Methylresorcinol*	77	Benzofuran	72
Anthracene*	76	Arsenic*	72
Fluoranthene*	76,72	Beryllium*	72
Fluorene*	76,72	Cadmium*	72
Naphthalene*	75,76,72	Lead*	72
Phenanthrene*	76,72	Mercury*	72
Pyrene*	76,72		

*Also found in quantified waste streams.

TABLE 4-6
CATEGORY D: STREAM CONSTITUENTS OF UNKNOWN TOXICITY

Substance	Source Stream
Perylene	72
Methylthiophene	75
Benzothiophene	75

TABLE 4-7
NON-TOXIC* SUBSTANCES IDENTIFIED IN SELECTED LURGI/FISCHER-TROPSCH PROCESS WATER STREAMS

Substances	Effluent Stream (s)
Propanoic Acid	29,53,72
Butanoic Acid	29,53,72
2-Methylpropanoic Acid	29,53,72
3-Methylbutanoic Acid	29,53,72
Ethane	72
Methane	72
C_2-C_6 Aliphatics	72
Boron	28,29,36,53,72
Manganese	28,36,53,69,72
Copper	36,69,72
Iron	69,72
Aluminum	69
Tin	28,36,72
Carbon Dioxide	28,72
N_2+inerts	28,72
O_2	28
H_2	28,72
H_2O	28,36,72
Ethanol	60

*Relative to human health.

The estimated post-dilution concentrations then were compared with acceptable human exposure levels, including Primary National Ambient Air Quality Standards, Drinking Water Standards, and Estimated Permissible Concentrations for human health.[36,37] Assumptions used in estimating dilution factors are presented in Table 4-8.

2) Post-dilution pollutant concentrations estimated using the SAM/I model also were used to project body burdens for selected stream constituents; the projected body burdens then were compared with body burdens from a coal-fired power plant, background concentration in air and water, and dietary intake.

Hazards posed by toxic stream constituents for which stream concentrations were unavailable (Category "C"), were assessed qualitatively, i.e., the potential impacts of exposure were identified. It was not possible to assess hazards posed by constituents for which neither toxicity nor concentration estimates were available (Category "D"). However, because these latter constituents may pose significant hazards to public health, research required to define and mitigate their risks was identified. The results of the assessments were integrated to identify and rank process waste streams and their constituents.

Finally, constituents of concern were ranked by degree of concern. The two most important criteria used in evaluating the degree of concern were 1) uncertainty regarding toxicologic and concentration data, and 2) the magnitude of the ratios of projected, post-dilution, pollutant concentrations to acceptable exposure levels. Three degrees of concern were specified for the classification:

- Probable Hazard - the highest level of concern, assigned to constituents which had a Post-dilution Concentration/Acceptable Exposure Level ratio greater than 10 and a moderate to high level of uncertainty regarding toxicologic or concentration data.

TABLE 4-8

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

STREAM	RECEIVING MEDIA	ASSUMPTIONS	DILUTION FACTOR
28-Utility Stack Gases	Atmosphere	- SAM/1 model utilized - Dilution factor is calculated for a a gaseous stream being discharged into the atmosphere at a flowrate of 8.75×10^5 g/sec - Ambient temperature = 25°C; Pressure = 1 atm. - Density of receiving air = 1.18 kg/m^3	235
29-Cooling Tower Atmospheric Losses	Atmosphere	- SAM/1 model utilized - Dilution factor is calculated for a gaseous discharge to the atmosphere at a flow rate of 1.55×10^7 gm/sec - Drift not modelled - Cooling water is composed of reverse osmosis permeate (Stream 54) and clean make-up water (Stream 31). - Ratio of contaminants to water in atmospheric emissions is equal to their ratio in cooling water. - Cooling water that is not lost by evaporation is recirculated - Effluent is at 100% humidity; Influent is at 0% humidity. - Density of receiving air = 1.18kg/m^3	30.4

TABLE 4-8 (Concluded)

STREAM	RECEIVING MEDIA	ASSUMPTIONS	DILITUON FACTOR
53-Reverse Osmosis Waste	Sump or Landfill then groundwater	- Flow rate of stream is 71,700 gm/sec - Stream is released to a sump or fill site - Eventual leakage of liquid into groundwater is expected - Local populace are expected to use groundwater directly for domestic needs.	10
69-Leachate from Gasifier and Utility Ash	Landfill, then Groundwater	- SAM/1 dilution factor utilized - Flow rate of the leachate = 7×10^6 gallons/yr (dependent on maximum rainfall) - Ash is disposed of at a fill site - Eventual leakage of liquid stream into groundwater is expected - Local populace are expected to use groundwater directly for domestic needs.	10
70-Biosludge	Not Evaluated	- Not evaluated	Not Evaluated
72-Lockhopper Vent Gas	Atmosphere	- SAM/1 model utilized - Dilution factor calculated for a gaseous stream being discharged into the atmosphere at a rate of 493 g/sec - Ambient temperature = $25^{\circ}C$; Pressure = 1 atm - Density of receiving air = 1.18 kg/m^3	24,000

- Possible Hazard - the intermediate level of concern, assigned to those constituents which had a Post-dilution Concentration/Acceptable Exposure Level ratio of 0.1 to 10.0, or a very high level of uncertainty regarding stream concentration or toxicologic data (e.g., category "D" constituents).
- Unlikely Hazard - the lowest level of concern, assigned to those constituents which had a Post-dilution Concentration/Acceptable Exposure Level of < 0.1 and a modest to high level of uncertainty regarding toxicologic or stream concentration data.

4.3 RESULTS

4.3.1 Comparison of Projected Post-dilution Concentrations with Acceptable Exposure Levels

Concentrations of toxic constituents have been estimated for five plant streams: utility stack gas (Stream 28); cooling tower atmospheric losses (Stream 29), coal lockhopper vent gas (Stream 72), reverse osmosis waste solution (Stream 53), and ash leachate (Stream 69). The estimated, post-dilution, ambient environmental concentrations of the potentially hazardous constituents, and the ratio of these concentrations to acceptable exposure levels (including Primary National Ambient Air Quality Standards, Drinking Water Standards, and Estimated Permissible Concentrations for Health) are described separately for each waste stream.

Utility Stack Gas (Stream 28) - Chemical characterization of Stream 28 is limited. Estimates of pollutant concentrations are available only for SO_x, NO_x and five trace elements. Estimated post-dilution concentrations of the pollutants and comparisons with Estimated Permissible Concentrations and Primary National Post-dilution Air Quality Standards are presented in Table 4-9. Inspection of the Ambient Concentration/Acceptable Exposure Level ratios indicates that none of the constituents fall into the Probable Hazards Category, but four are projected to be Possible Hazards: arsenic, mercury, SO_x and NO_x. Arsenic and mercury approach, but do not exceed the relevant EPC_{AH}; Primary National Ambient Air Quality Standards have not been promulgated for either metal. Estimated ambient concentrations for SO_x and NO_x

TABLE 4-9: UTILITY STACK GAS POLLUTANTS (STREAM 28): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS WITH PUBLIC HEALTH BENCHMARKS.

	A Estimated Post-Dilution (μg/m^3)	B EPC$_{All}$[a] (μg/m^3)	A/B	C Primary[b] NAAQS (μg/m^3)	A/C
TRACE ELEMENTS					
Aluminum					
Arsenic	5.8E-4	5.0E-3	1.2E-1		
Beryllium	6.1E-4	1.0E-2	6.1E-2		
Boron		7.4			
Cadmium	5.1E-4	1.2E-1	4.3E-3		
Copper					
Fluorine					
Iron					
Lead	6.0E-3	3.6E-1	1.7E-2	1.5	4.0E-3
Manganese					
Mercury	3.9E-2	1.0E-1	3.9E-1		
Nickel		2.4E-1			
Selenium		5.0E-1			
Vanadium		1.2			
Zinc					
TOTAL TRACE ELEMENTS					
ALIPHATICS, ALICYCLICS AND FATTY ACIDS					
Acetic Acid		6.0E+1			
Butanoic Acid		1.0E+1			
Hexanoic Acid					
3-Methylbutanoic Acid					
2-Methylpropanoic Acid					
Pentanoic Acid		4.1E+1			
Propanoic Acid					
TOTAL FATTY ACIDS					
BENZENES & SUBSTITUTED BENZENES					
Biphenyl		2.4			
Ethylbenzene		1.0E+3			
Indan		4.0E+2			
Toluene		8.9E+2			
1,2,4-Trimethylbenzene					
o-Xylene		1.0E+3			

TABLE 4-9 (Continued)

	A Estimated Post-Dilution (μg/m^3)	B EPC$_{AH}$[a] (μg/m^3)	A/B	C Primary[b] NAAQS (μg/m^3)	A/C
NITROGEN HETEROCYCLICS					
2,4-Dimethylpyridine		3.2E+1			
2,5-Dimethylpyridine		3.2E+1			
2-Methylpyridine		6.4E+1			
3-Methylpyridine		6.4E+1			
4-Methylpyridine		6.4E+1			
Pyridine		3.6E+1			
Quinoline		2.8E+1			
OXYGEN HETEROCYCLICS					
Benzofuran					
Dibenzofuran					
MERCAPTANS					
Methanethiol		2.4			
TOTAL MERCAPTANS					
AROMATIC AMINES					
Aniline		4.5			
TOTAL AROMATIC AMINES					
NITROSAMINES					
MISCELLANEOUS					
Ammonia		4.3E+1			
Carbonyl Sulfide		8.0E+2			
Hydrogen Cyanide		2.6E+1			
Hydrogen Sulfide		3.6E+1			
Nickel Carbonyl		1.0E-1			
NO$_x$	1.3E+2			1.0E+2	1.3
Particulates	2.0			75	2.7E-2
SO$_x$	7.0E+2			8.0E+1	8.8
Tars, Oils, Naphtha					

TABLE 4-9 (Continued)

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC^a_{AH} ($\mu g/m^3$)	A/B	C Primary NAAQS ($\mu g/m^3$)	A/C
PHENOLS					
Catechol		4.8E+1			
3,6-Dimethylcatechol					
3-Methylcatechol					
4-Methylcatechol					
2-Methylphenol		5.2E+1			
3-Methylphenol		2.4E+1			
4-Methylphenol		2.4E+1			
4-Methylresorcinol					
5-Methylresorcinol					
Phenol		4.5E+1			
Resorcinol		1.1E+2			
2,4-Xylenol		2.4E+1			
3,5-Xylenol		2.4E+1			
TOTAL PHENOLS					
POLYNUCLEAR AROMATIC HYDROCARBONS					
Acenaphthalene					
Anthracene					
Benz(a)anthracene		8.1E-1			
Benzo(g,h,i)perylene					
Benzo(a)pyrene		4.0			
Benzo(e)pyrene					
Chrysene		1.6E+2			
Fluoranthene					
Fluorene					
Naphthalene		1.2E+2			
Perylene					
Phenanthrene		5.7E+1			
Pyrene					
TOTAL PAH's					
SULFUR HETEROCYCLICS					
Methylthiophene		4.1E+1			
Thiophene		8.0			
TOTAL THIOPHENES					

TABLE 4-9 (Concluded)

[a] Estimated Permissible Concentration in Air for Protection of Human Health[34-37]

[b] Primary National Ambient Air Quality Standards[80]

exceed relevant Primary National Ambient Air Quality Standards, but it must be noted that the projected post-dilution concentrations represent maximum ground-level concentrations, not ambient concentrations for an airshed.

Atmospheric Losses from the Cooling Tower (Stream 29) - Characterization data for cooling tower atmospheric losses are very limited. Post-dilution concentrations have been estimated under the assumption that the cooling water is composed of treated process effluents, boiler blowdown and make-up water. Losses are assumed to be evaporative; no modeling of drift or estimates of pollutant partitioning between drift and evaporative phases has been attempted. Projected post-dilution concentrations and comparisons with acceptable exposure levels are presented in Table 4-10.

Inspection of the results indicates that none of the constituents of Stream 29 are Probable Hazards, but two constituents, arsenic and ammonia, exceed their relevant EPC_{AH} and are classified as Possible Hazards.

Reverse Osmosis Waste Solution (Stream 53) - Stream 53 is the largest aqueous waste stream and contains organics and trace elements. Characterizations of organics and trace elements have been estimated using available data. Post-dilution environmental concentrations and comparisons with Estimated Permissible Concentration in water for the protection of human health (EPC_{WH}) and Drinking Water Standards are presented in Table 4-11.

The results indicate that trace elements, phenols and mercaptans each contain at least one constituent that is classified as a Probable Hazard. Five groups (trace elements, aliphatics and fatty acids, benzene and substituted benzenes, phenols, and polynuclear aromatic hydrocarbons) have at least one constituent member in the Possible Hazard Category.

Estimates of stream concentrations and acceptable exposure levels are available for eight trace elements. All of the eight elements are

TABLE 4-10: COOLING TOWER EVAPORATIVE LOSSES (STREAM 29): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS WITH PUBLIC HEALTH BENCHMARKS.

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC_{AH}[a] ($\mu g/m^3$)	A/B	C Primary NAAQS[b] ($\mu g/m^3$)	A/C
TRACE ELEMENTS					
Aluminum					
Arsenic	1.3E-2	5.0E-3	2.6		
Beryllium	6.5E-3	8.0-E-1	8.1E-3		
Boron	4.3E-2	7.4	5.8E-3		
Cadmium	7.5E-3	1.2E-1	6.3E-2		
Copper					
Fluorine	3.1E-1				
Iron					
Lead	1.5E-2	3.6E-1	4.2E-2	1.5	1.0E-2
Manganese					
Mercury	1.1E-3	1.0E-1	1.1E-2		
Nickel	4.0E-3	2.4E-1	1.7E-3		
Selenium		5.0E-1			
Vanadium	1.1E-4	1.2	8.3E-5		
Zinc					
TOTAL TRACE ELEMENTS					
ALIPHATICS, ALICYCLICS AND FATTY ACIDS					
Acetic Acid	1.6	6.0E+1	2.7E-2		
Butanoic Acid	9.1E-2				
Hexanoic Acid	6.9E-3	1.0E+1	6.6E-4		
3-Methylbutanoic Acid	6.9E-3				
2-Methylpropanoic Acid	1.4E-2				
Pentanoic Acid	8.4E-2	4.1E+1	2.1E-3		
Propanoic Acid	1.7E-1				
TOTAL FATTY ACIDS					
BENZENES & SUBSTITUTED BENZENES					
Biphenyl	7.6E-4	2.4	3.2E-4		
Ethylbenzene	2.1E-1	1.0E+3	2.0E-4		
Indan	9.9E-3	4.0E+2	2.4E-5		
Toluene	6.9E-1	8.9E+2	7.8E-4		
1,2,4-Trimethylbenzene					
o-Xylene	2.4E-1	1.0E+3	2.0E-4		

TABLE 4-10 (Continued)

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC_{AH} ($\mu g/m^3$)	A/B	C Primary NAAQS ($\mu g/m^3$)	A/C
<u>PHENOLS</u>					
Catechol	7.2E-1	4.8E+1	1.5E-2		
3,6-Dimethylcatechol	5.9E-1				
3-Methylcatechol	0.0				
4-Methylcatechol	5.1E-1				
2-Methylphenol	5.9E-3	5.2E+1	2.5E-4		
3-Methylphenol	3.6E-3	2.4E+1	1.5E-4		
4-Methylphenol	4.9E-3	2.4E+1	2.0E-4		
4-Methylresorcinol	4.7E-2				
5-Methylresorcinol	8.4E-2				
Phenol	2.1E-2	4.5E+1	4.7E-4		
Resorcinol	2.4E-1	1.1E+2	2.2E-3		
2,4-Xylenol	5.0E-3	2.4E+1	2.1E-4		
3,5-Xylenol	5.0E-3	2.4E+1	2.9E-4		
TOTAL PHENOLS					
<u>POLYNUCLEAR AROMATIC HYDROCARBONS</u>					
Acenaphthalene	1.5E-4				
Anthracene	3.7E-6				
Benz(a)anthracene	3.7E-6	8.1E-1	4.6E-6		
Benzo(g,h,i)perylene	1.4E-2				
Benzo(a)pyrene	1.5E-6	4.0	3.7E-7		
Benzo(e)pyrene	1.5E-6	2.0			
Chrysene	7.5E-7				
Fluoranthene	7.4E-5	1.6E+2	4.6E-7		
Fluorene	7.4E-5				
Naphthalene	3.6E-3	1.2E+2	3.0E-5		
Perylene	1.5E-7				
Phenanthrene	3.7E-5	5.7E+1	6.5E-7		
Pyrene	7.4E-5				
TOTAL PAH's					
<u>SULFUR HETEROCYCLICS</u>					
Methylthiophene		4.1E+7			
Thiophene		8.0			
TOTAL THIOPHENES					

TABLE 4-10 (Continued)

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC_{AH} ($\mu g/m^3$)	A/B	C Primary NAAQS ($\mu g/m^3$)	A/C
NITROGEN HETEROCYCLICS					
2,4-Dimethylpyridine	1.1E-4	3.2E+1	3.4E-6		
2,5-Dimethylpyridine	1.1E-4	3.2E+1	3.4E-6		
2-Methylpyridine	8.4E-3	6.4E+1	1.3E-4		
3-Methylpyridine	2.0E-3	6.4E+1	4.7E-5		
4-Methylpyridine	6.9E-4	6.4E+1	1.1E-5		
Pyridine	1.4E-3	3.6E+1	3.9E-5		
Quinoline	1.1E-3	2.8E+1	3.9E-5		
OXYGEN HETEROCYCLICS					
Benzofuran					
Dibenzofuran	1.0E-3				
MERCAPTANS					
Methanethiol	8.4E-2	2.4	3.5E-2		
TOTAL MERCAPTANS					
AROMATIC AMINES					
Aniline	1.0E-3	4.5E+1	2.2E-2		
TOTAL AROMATIC AMINES					
NITROSAMINES					
MISCELLANEOUS					
Ammonia	2.0E+1	4.3E+1	4.7E-1		
Carbonyl Sulfide		8.0E+2			
Hydrogen Cyanide		2.6E+1			
Hydrogen Sulfide		3.6E+1			
Nickel Carbonyl		1.0E-1			
NO_x				1.0E+2	
Particulates					
SO_x				8.0E+1	
Tars, Oils, Naphtha					

TABLE 4-10 (Concluded)

[a] Estimated Permissible Concentration in Air for Protection of Human Health[34-37]

[b] Primary National Ambient Air Quality Standards[80]

TABLE 4-11: REVERSE OSMOSIS WASTE (STREAM 53): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS OF METALS AND ORGANICS WITH PUBLIC HEALTH BENCHMARKS.

	A Estimated Post-Dilution (mg/l)	B EPC_{WH} [a] (mg/l)	A/B	C [a b] Drinking Water Standards (mg/l)	A/C
TRACE ELEMENTS					
Aluminum		7.3E-2			
Arsenic	8.9E-2			5.0E-2	1.8
Beryllium	4.6E-2	4.0E-3	1.2E+1		
Boron	3.1E-1	4.3E-2	7.2		
Cadmium	5.3E-3			1.0E-2	5.3E-1
Copper		1.0			
Fluorine	3.3				
Iron					
Lead	1.7E-2			5.0E-2	3.4E-1
Manganese	8.8E-2				
Mercury	8.1E-3			2.0E-3	4.0
Nickel	1.5E-2	1.4E-3	1.1E+1		
Selenium				1.0E-2	
Vanadium	1.8E-3	7.0E-3	2.6E-1		
Zinc					
TOTAL TRACE ELEMENTS					
ALIPHATICS, ALICYCLICS AND FATTY ACIDS					
Acetic Acid	1.3	3.5E-1	3.8		
Butanoic Acid	1.2E-1				
Hexanoic Acid	9.4E-3	5.1E-2	1.8E-1		
3-Methylbutanoic Acid	9.4E-3				
2-Methylpropanoic Acid	1.9E-2				
Pentanoic Acid	1.1E-1	2.0E-1	5.5E-1		
Propanoic Acid	2.5E-1				
TOTAL FATTY ACIDS					
BENZENES & SUBSTITUTED BENZENES					
Biphenyl	6.2E-2	1.4E-2	4.4		
Ethylbenzene	2.9E-1	6.0	4.8E-2		
Indan	7.9E-1	2.0	4.0E-1		
Toluene	9.4E-1	5.2	1.8E-1		
1,2,4-Trimethylbenzene					
o-Xylene	3.3E-1	6.0	5.4E-2		

TABLE 4-11 (Continued)

	A Estimated Post-Dilution (mg/l)	B EPC_{WH} (mg/l)	A/B	C Drinking Water Standards (mg/l)	A/C
PHENOLS					
Catechol	1.7	2.8E-1	6.1	1.0E-3	1.7E+3
3,6-Dimethylcatechol	1.4E-1			1.0E-3	1.4E+2
3-Methylcatechol	0.0			1.0E-3	0.0
4-Methylcatechol	1.2			1.0E-3	1.2E+3
2-Methylphenol	1.3E-2	1.4E-1	9.4E-2	1.0E-3	1.3E+1
3-Methylphenol	1.9E-2	1.4E-1	1.4E-1	1.0E-3	1.9E+1
4-Methylphenol	1.2E-2	1.4E-1	8.7E-2	1.0E-3	1.2E+1
4-Methylresorcinol	1.1E-1			1.0E-3	1.1E+2
5-Methylresorcinol	2.1E-1			1.0E-3	2.1E+2
Phenol	3.8E-2	2.6E-1	1.5E-1	1.0E-3	3.8E+1
Resorcinol	5.8E-1	6.2E-1	9.3E-1	1.0E-3	5.8E+2
2,4-Xylenol	3.6E-2	1.2E-1	3.0E-1	1.0E-3	3.6E+1
3,5-Xylenol	5.0E-2	1.2E-1	3.0E-1	1.0E-3	5.0E+1
TOTAL PHENOLS	4.1			1.0E-3	4.1E+3
POLYNUCLEAR AROMATIC HYDROCARBONS					
Acenaphthalene	1.2E-2				
Anthracene	3.0E-3				
Benz(a)anthracene	3.0E-4	4.0E-3	7.5E-2		
Benzo(g,h,i)perylene	8.9E-6				
Benzo(a)pyrene	1.2E-4	2.0E-2	6.0E-2		
Benzo(e)pyrene	1.2E-4				
Chrysene	5.9E-5				
Fluoranthene	5.9E-3	8.0E-1	7.0E-3		
Fluorene	5.9E-3				
Naphthalene	2.8E-1	6.9E-1	4.1E-1		
Perylene	1.2E-5				
Phenanthrene	3.0E-3	2.8E-1	1.1E-2		
Pyrene	5.9E-3				
TOTAL PAH's					
SULFUR HETEROCYCLICS					
Methylthiophene					
Thiophene					
TOTAL THIOPHENES					

TABLE 4-11 (Continued)

	A Estimated Post-Dilution (mg/l)	B EPC_{WH}	A/B	C Drinking Water Standards (mg/l)	A/C
NITROGEN HETEROCYCLICS					
2,4-Dimethylpyridine	2.6E-4	1.6E-1	1.6E-2		
2,5-Dimethylpyridine	2.6E-4	1.6E-1	1.6E-2		
2-Methylpyridine	1.8E-2	3.2E-1	5.7E-2		
3-Methylpyridine	6.7E-3	3.2E-1	2.1E-2		
4-Methylpyridine	1.6E-3	3.6E-1	5.1E-3		
Pyridine	3.0E-3	2.1E-1	1.4E-2		
Quinoline	2.5E-3	1.4E-1	1.8E-2		
OXYGEN HETEROCYCLICS					
Benzofuran					
Dibenzofuran	2.2E-3				
MERCAPTANS					
Methanethiol	5.9E-1	1.4E-2	4.2E+1		
TOTAL MERCAPTANS					
AROMATIC AMINES					
Aniline	1.3E-3	2.6E-3	5.0E-3		
TOTAL AROMATIC AMINES					
NITROSAMINES					
MISCELLANEOUS					
Ammonia					
Carbonyl Sulfide					
Hydrogen Cyanide					
Hydrogen Sulfide					
Nickel Carbonyl					
NO_x					
Particulates					
SO_x					
Tars, Oil, Naphtha					

TABLE 4-11 (Concluded)

[a] Estimated Permissible Concentration in Air for Protection of Human Health[34-37]

[b] Primary National Ambient Air Quality Standards[80]

projected to be either Probable Hazards or Possible Hazards. Beryllium and nickel are classified as Probable Hazards, but their Post-dilution Concentration/EPC$_{WH}$ ratios, 12 and 11 respectively, are not considerably greater than the ratios for the Possible Hazards. Trace elements which are projected to be Possible Hazards are arsenic, boron, cadmium, lead, mercury and vanadium. Of these six elements, two exceed Safe Drinking Water Standards (arsenic by a factor of approximately 2 and mercury by a factor of 4); two approach the Safe Drinking Water Standards (cadmium and lead); boron exceeds its EPC$_{WH}$; and vanadium approaches its EPC$_{WH}$.

Methanethiol, the only mercaptan evaluated in the analysis, is categorized as a Probable Hazard, with a Post-dilution Concentration/ EPC$_{WH}$ of 42.

All of the phenols are projected to be Probable Hazards based on their Post-dilution Concentration/Safe Drinking Water Standard ratios. However it should be noted that the Drinking Water Standard for phenols is based on the organoleptic properties of phenol, not toxicity. As such the risks to public health may be considerably lower than would be implied by these relatively high ratios. Based on the Post-dilution Concentration/EPC$_{WH}$ ratios, more of the phenolic compounds are classified as Probable Hazards, but six are Possible Hazards, i.e., catechol, 3-methylphenol, phenol, resorcinol, 2,4-xylenol and 3,5-xylenol.

Three fatty acids are projected to be Possible Hazards, based on their Ambient Concentration/EPC$_{WH}$ ratios. Of the three, acetic acid exceeds the EPC$_{WH}$, and hexanoic acid and pentanoic acid approach the EPC$_{WH}$.

Three substituted benzenes also are projected to be Possible Hazards: biphenyl exceeds the EPC$_{WH}$; and toluene and indan approach their EPC$_{WH}$ values.

One polynuclear aromatic hydrocarbon, naphthalene, is projected to approaches its EPC$_{WH}$, and is classified as a Possible Hazard.

Ash Leachate (Stream 69) - The ash leachate stream has been characterized only with respect to trace elements because data regarding organic compounds could not be obtained. Results are presented in Table 4-12. None of the trace elements are categorized as Probable Hazards, but four are projected to be Possible Hazards. Of the four, nickel exceeds the EPC_{WH}, lead and selenium approach their Safe Drinking Water Standards, and aluminum approaches the EPC_{WH}.

Lockhopper Vent Gas (Stream 72) - The composition of the lockhopper vent gas is assumed to be the same as that of the gasifier product gas. Estimates of concentrations are available for classes of constituents, not individual compounds.

EPCs are not available for classes of compounds; therefore, the lowest EPC_{AH} for any constituent in a class is used to calculate the Post-dilution Concentration/EPC_{AH} for each class, e.g., the EPC_{AH} for arsenic (the most toxic trace metal) is used to estimate the Post-dilution Concentration/EPC_{AH} ratio for trace elements. Results are presented in Table 4-13.

None of the constituents are projected to be Probable Hazards. However, seven constituents or classes of constituents are projected to be Possible Hazards. Of the seven, total trace elements, ammonia, hydrogen sulfide, total fatty acids, and total phenols exceed the most stringent EPC_{AH} for any member in this group. Nickel carbonyl and mercaptans approach the most stringent EPC_{AH} for any constituent in this group.

It should be noted that under normal operations the vent gas will be flared which will combust most organics while having little effect on the trace elements. The extent of organic degradation depends on the heat of the flare and the duration of the burn. The potential for large releases with acute impact during startup, shutdown and upset operations, and the potential chronic impact of low level exposure to vent gas constituents suggests the need for further characterization and assessment of this stream.

TABLE 4-12: GASIFIER ASH LEACHATES (STREAM 69): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS WITH PUBLIC HEALTH BENCHMARKS

	A Estimated Post-Dilution (mg/l)	B EPC$_{WH}^{a}$ (mg/l)	A/B	C Drinking Water Standards^{a,b} (mg/l)	A/C
TRACE ELEMENTS					
Aluminum	2.0E-2	7.3E-2	2.7-E-1		
Arsenic	2.0E-3			5.0E-2	4.0E-2
Beryllium		4.0E-3			
Boron		4.3E-2			
Cadmium	6.4E-5			1.0E-2	6.4E-3
Copper	3.0E-3	1.0	3.0E-3		
Fluorine					
Iron	1.6E-1				
Lead	9.3E-3			5.0E-2	1.8E-1
Manganese					
Mercury	3.0E-5			2.0E-3	1.5E-2
Nickel	3.5E-3	1.4E-3	2.5		
Selenium	6.0E-3			1.0E-2	6.0E-1
Vanadium		7.0E-3			
Zinc	2.9E-4			5.0	5.8E-5
TOTAL TRACE ELEMENTS					
ALIPHATICS, ALICYCLICS AND FATTY ACIDS					
Acetic Acid		3.5E-1			
Butanoic Acid					
Hexanoic Acid		5.1E-2			
3-Methylbutanoic Acid					
2-Methylpropanoic Acid					
Pentanoic Acid		2.0E-1			
Propanoic Acid					
TOTAL FATTY ACIDS					
BENZENES & SUBSTITUTED BENZENES					
Biphenyl		1.4E-2			
Ethylbenzene		6.0			
Indan		2.0			
Toluene		5.2			
1,2,4-Trimethylbenzene					
o-Xylene		6.0			

TABLE 4-12 (Continued)

	A	B	A/B	C	A/C
	Estimated Post-Dilution (mg/l)	EPC$_{WH}$ (mg/l)		Drinking Water Standards (mg/l)	
PHENOLS					
Catechol		2.8E-1		1.0E-3	
3,6-Dimethylcatechol				1.0E-3	
3-Methylcatechol				1.0E-3	
4-Methylcatechol				1.0E-3	
2-Methylphenol		1.4E-1		1.0E-3	
3-Methylphenol		1.4E-1		1.0E-3	
4-Methylphenol		1.4E-1		1.0E-3	
4-Methylresorcinol				1.0E-3	
5-Methylresorcinol				1.0E-3	
Phenol		2.6E-1		1.0E-3	
Resorcinol		6.2E-1		1.0E-3	
2,4-Xylenol		1.2E-1		1.0E-3	
3,5-Xylenol		1.2E-1		1.0E-3	
TOTAL PHENOLS				1.0E-3	
POLYNUCLEAR AROMATIC HYDROCARBONS					
Acenaphthalene					
Anthracene					
Benz(a)anthracene		4.0E-3			
Benzo(g,h,i)perylene					
Benzo(a)pyrene		2.0E-2			
Benzo(e)pyrene					
Chrysene					
Fluoranthene		8.0E-1			
Fluorene					
Naphthalene		6.9E-1			
Perylene					
Phenanthrene		2.8E-1			
Pyrene					
TOTAL PAH's					
SULFUR HETEROCYCLICS					
Methylthiophene					
Thiophene					
TOTAL THIOPHENES					

TABLE 4-12 (Continued)

	A Estimated Post-Dilution (mg/1)	B EPC_{WH} (mg/1)	A/B	C Drinking Water Standards (mg/1)	A/C
NITROGEN HETEROCYCLICS					
2,4-Dimethylpyridine		1.6E-1			
2,5-Dimethylpyridine		1.6E-1			
2-Methylpyridine		3.2E-1			
3-Methylpyridine		3.2E-1			
4-Methylpyridine		3.6E-1			
Pyridine		2.1E-1			
Quinoline		1.4E-1			
OXYGEN HETEROCYCLICS					
Benzofuran					
Dibenzofuran					
MERCAPTANS					
Methanethiol		1.4E-2			
TOTAL MERCAPTANS					
AROMATIC AMINES					
Aniline		2.6E-1			
TOTAL AROMATIC AMINES					
NITROSAMINES					
MISCELLANEOUS					
Ammonia					
Carbonyl Sulfide					
Hydrogen Cyanide					
Hydrogen Sulfide					
Nickel Carbonyl					
NO_x					
Particulates					
SO_x					
Tars, Oils, Naphtha					

TABLE 4-12 (Concluded)

[a] Estimated Permissible Concentration in Air for Protection of Human Health[34-37]

[b] Primary National Ambient Air Quality Standards[38]

TABLE 4-13: LOCKHOPPER VENT GAS EMISSIONS (STREAM 72): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRATIONS WITH PUBLIC HEALTH BENCHMARKS.

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC[a]$_{AH}$ ($\mu g/m^3$)	A/B	C Primary[b] NAAQS ($\mu g/m^3$)	A/C
TRACE ELEMENTS					
Aluminum					
Arsenic		5.0E-3			
Beryllium					
Boron		7.4			
Cadmium		1.2E-1			
Copper					
Fluorine					
Iron					
Lead		3.6E-1		1.5	
Manganese					
Mercury		1.0E-1			
Nickel		2.4E-1			
Selenium		5.0E-1			
Vanadium		1.2			
Zinc					
TOTAL TRACE ELEMENTS	2.5E-2		5.0		
ALIPHATICS, ALICYCLICS AND FATTY ACIDS					
Acetic Acid			6.0E+1		
Butanoic Acid					
Hexanoic Acid			1.0E+1		
3-Methylbutanoic Acid					
2-Methylpropanoic Acid					
Pentanoic Acid			4.1E+1		
Propanoic Acid					
TOTAL FATTY ACIDS	1.3E+1		1.3[c]		
BENZENES & SUBSTITUTED BENZENES					
Biphenyl		2.4			
Ethylbenzene		1.0E+3			
Indan		4.0E+2			
Toluene		8.9E+2			
1,2,4-Trimethylbenzene					
o-Xylene		1.0E+3			

TABLE 4-13 (Continued)

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC[a]$_{AH}$ ($\mu g/m^3$)	A/B	C Primary[b] NAAQS ($\mu g/m^3$)	A/C
PHENOLS					
Catechol		4.8E+1			
3,6-Dimethylcatechol					
3-Methylcatechol					
4-Methylcatechol					
2-Methylphenol		5.2E+1			
3-Methylphenol		2.4E+1			
4-Methylphenol		2.4E+1			
4-Methylresorcinol					
5-Methylresorcinol					
Phenol		4.5E+1			
Resorcinol		1.1E+2			
2,4-Xylenol		2.4E+1			
3,5-Xylenol		2.4E+1			
TOTAL PHENOLS	6.4E+1		2.7[c]		
POLYNUCLEAR AROMATIC HYDROCARBONS					
Acenaphthalene					
Anthracene					
Benz(a)anthracene		8.1E-1			
Benzo(g,h,i)perylene					
Benzo(a)pyrene		4.0			
Benzo(e)pyrene					
Chrysene					
Fluoranthene		1.6E+2			
Fluorene					
Naphthalene		1.2E+2			
Perylene					
Phenanthrene		5.7E+1			
Pyrene					
TOTAL PAH's	2.5E-2		3.0E-2[c]		
SULFUR HETEROCYCLICS					
Methylthiophene		4.1E+1			
Thiophene		8.0			
TOTAL THIOPHENES	2.0E-1		2.5E-2[c]		

TABLE 4-13 (Continued)

	A Estimated Post-Dilution ($\mu g/m^3$)	B EPC^{a}_{AH} ($\mu g/m^3$)	A/B	C Primary[b] NAAQS ($\mu g/m^3$)	A/C
NITROGEN HETEROCYCLICS					
2,4-Dimethylpyridine		3.2E+1			
2,5-Dimethylpyridine		3.2E+1			
2-Methylpyridine		6.4E+1			
3-Methylpyridine		6.4E+1			
4-Methylpyridine		6.4E+1			
Pyridine		3.6E+1			
Quinoline		2.8E+1			
OXYGEN HETEROCYCLICS					
Benzofuran					
Dibenzofuran					
MERCAPTANS					
Methanethiol		2.4			
TOTAL MERCAPTANS	2.5E-1		1.0E-1[c]		
AROMATIC AMINES					
Aniline		4.5E+1			
TOTAL AROMATIC AMINES	4.9E-2		1.1E-3[c]		
NITROSAMINES	2.5E-2				
MISCELLANEOUS					
Ammonia	9.8E+1	4.3E+1	2.3		
Carbonyl Sulfide	1.4	8.0E+2	1.8E-3		
Hydrogen Cyanide	9.6E-2	2.6E+1	3.7E-3		
Hydrogen Sulfide	6.6E+2	3.6E+1	1.8		
Nickel Carbonyl	7.4E-2	1.0E-1	7.4E-1		
NO_x				1.0E+2	
Particulates					
SO_x				8.0E+1	
Tars, Oil, Naphtha	7.3E+2				

TABLE 4-13 (Concluded)

[a] Estimated Permissible Concentration in Air for Protection of Human Health[34-37]

[b] Primary National Ambient Air Quality Standards[80]

4.3.2 Body Burdens

Quantification of the impact on human health from exposures to Lurgi/Fischer-Tropsch environmental releases is desirable. Unfortunately dose-response data are not available for many of the pollutants that may be released by the Lurgi/Fischer-Tropsch facility, making determination of the absolute number and type of adverse impacts impossible. It is possible, however, to calculate body burdens for substances for which the exposure concentrations, routes of entry, absorption and biological half life are known. Body burdens represent the amount of substance that accumulates within a receptor. Body burdens can be calculated for different sources of exposure and different routes of entry to the body. Results can be compared to provide a measure of the relative risk of exposure.

Exposure, route of entry, absorption and biological half life data are available for many trace elements released by the Lurgi/Fischer-Tropsch process. Body burdens for three representative trace elements (arsenic, cadmium, and lead) produced by the Lurgi/Fischer-Tropsch plant were calculated using the Argonne Body Burden model (described in more detail in Volume IV). These three elements were chosen because they are all highly toxic and encompass the known range of absorption and biological half life of other trace elements. Body burdens were calculated for four sources of exposure (background air and water, diet, a 1000 MWe coal-fired power plant, and the Lurgi/Fischer-Tropsch facility), and two routes of entry (respiratory and the gastrointestinal tract). Body burdens represent amount of element per gram of tissue accumulating in an exposed 70 kg male who breathes 20 m^3 of air per day and drinks 2 liters of water per day.

Contributions to trace element exposure from Lurgi/Fischer-Tropsch facilities were based on projected post-dilution, pollutant concentrations resulting from discharge of utility stack gases, cooling tower atmospheric losses, reverse osmosis wastes and ash leachate, presented in Table 4-9, 4-10, 4-11, and 4-12, respectively. Contributions from a 1000 MWe coal-fired power plant were based on projected ambient concentrations for such a facility burning #6 Illinois coal located in Fulton County, Illinois. Contributions attributed to background air and water represented national averages as determined by U.S. EPA monitoring programs. Contributions from diet represent average U.S. dietary characteristics. Results of the body burden calculations are presented in Figures 4-2, 4-3, and 4-4.

As Figure 4-2 illustrates, the body burden of arsenic from exposure to Lurgi/Fischer-Tropsch environmental wastes is double that from the coal-fired power plant and background air and water concentrations, but only half that from dietary intake. The primary route of entry that results in these levels is the gastrointestinal tract, underscoring the significance of the aqueous waste streams (reverse osmosis, ash leachate) that contribute arsenic to aquatic systems.

The body burden of cadmium (Figure 4-3) resulting from exposure to Lurgi/Fischer-Tropsch environmental wastes is less than 40% of that from coal-fired power plants, approximately 60% of that from background air and water exposures, and less than two percent of that resulting from exposure to cadmium in diet. As in the case of arsenic the primary route of entry for cadmium is the gastrointestinal tract, again reflecting the importance of aqueous waste streams which contribute cadmium to the aquatic environment.

The body burdens of lead (Figure 4-4), a trace element with a long biological half life, resulting from exposure to Lurgi/Fischer-Tropsch environmental wastes, is approximately half that from coal-fired power plant exposures, and background air and water exposure, and one tenth that from diet. The gastrointestinal route of entry accounts for approximately 99 percent of the total burdens of lead.

Comparing the body burdens of the three representative trace elements from the four assessment sources of exposure provides a measure

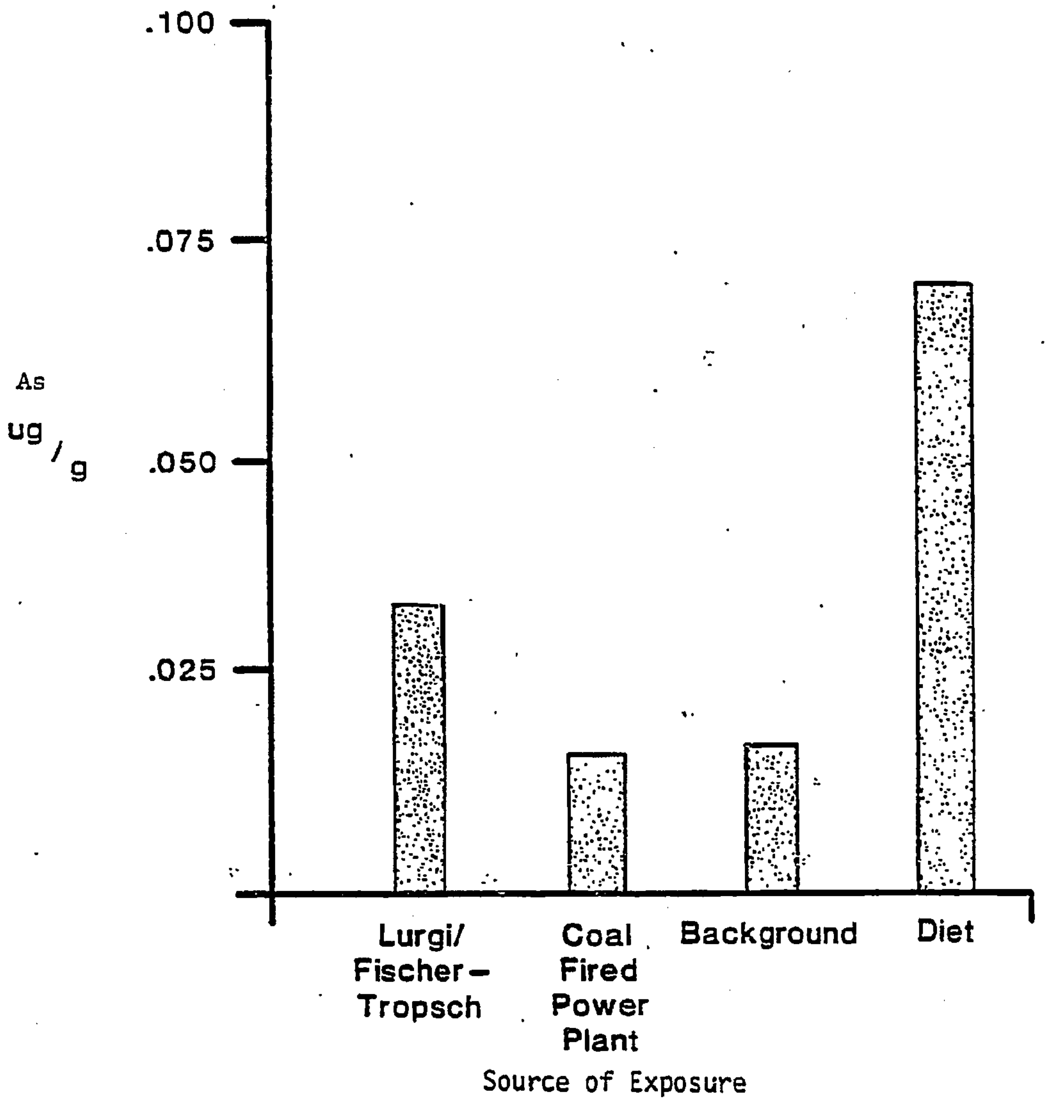
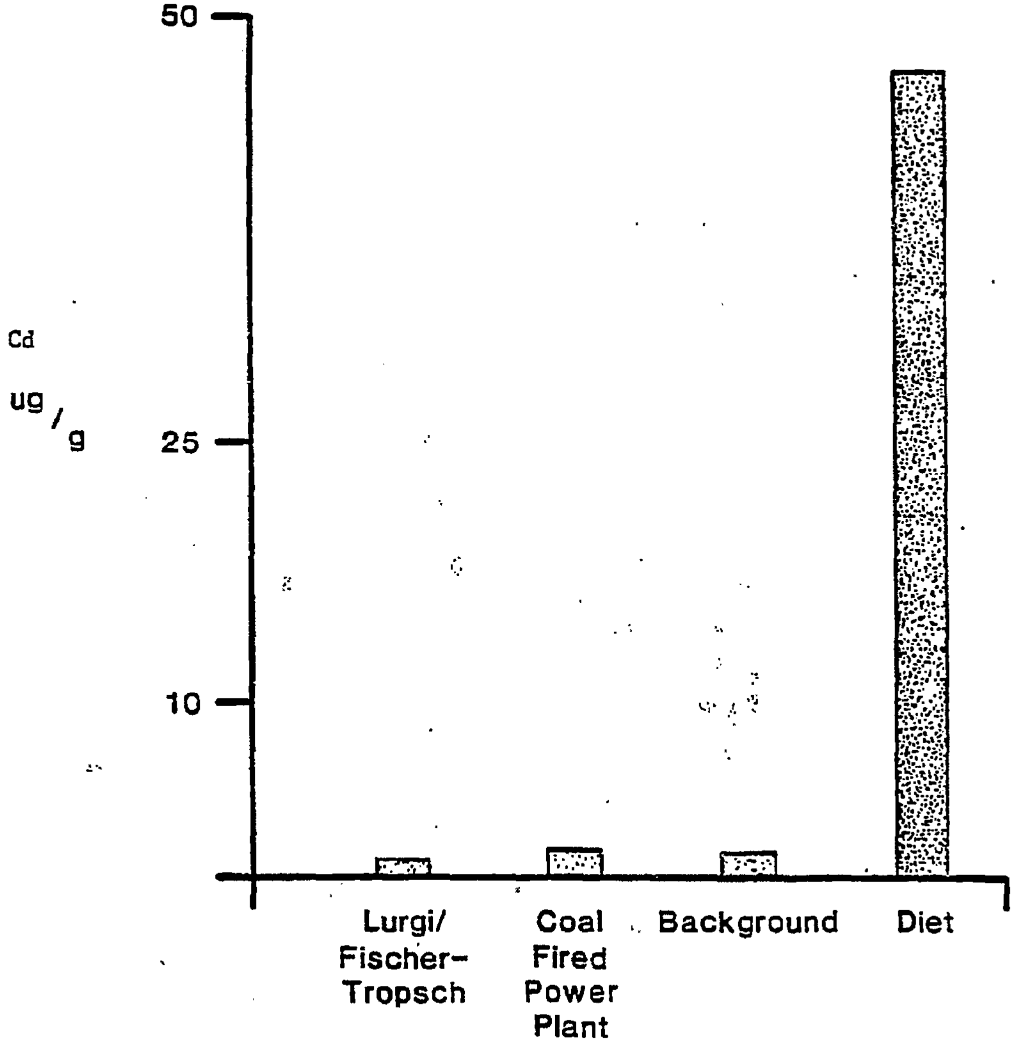


FIGURE 4-2

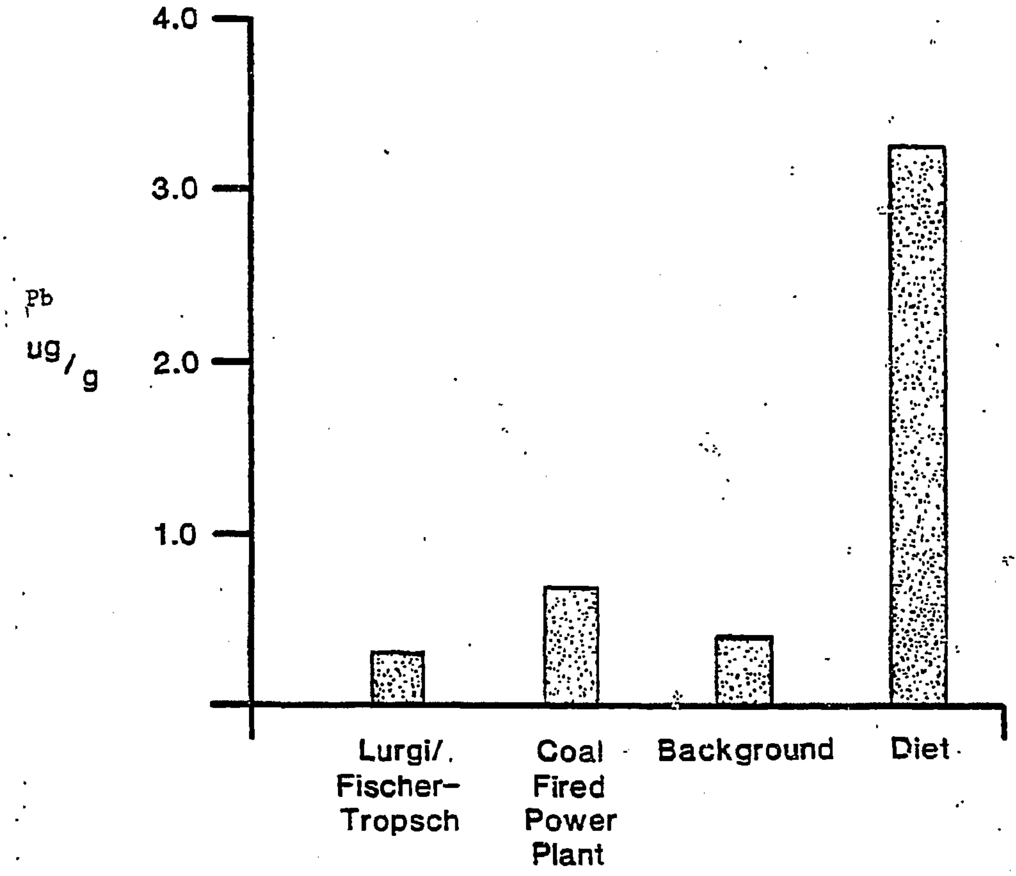
BODY BURDENS OF ARSENIC RESULTING FROM FOUR SOURCES OF EXPOSURE



Source of Exposure

FIGURE 4-3

BODY BURDENS OF CADMIUM RESULTING FROM FOUR SOURCES OF EXPOSURE



Source of Exposure

FIGURE 4-4

BODY BURDENS OF LEAD RESULTING FROM FOUR SOURCES OF EXPOSURE.

for estimating the potential for adverse health impacts from each source. The magnitude and severity of any adverse impact will depend upon the total body burden from all sources of exposure and a currently unquantifiable threshold level for effect. However, comparison of body burden can be used to estimate the relative risk from each source of exposure. Two factors may effect these results. Several potential sources of trace element release from Lurgi/Fischer-Tropsch were not quantified in the technology characterization used in this assessment. Additionally no accounting was made for those trace elements released to the environment through combustion of Lurgi/Fischer-Tropsch product liquids. Both factors would potentially alter the subsequent effects on body burdens calculations.

4.4 DISCUSSION

Pollutants that are projected to be Probable or Possible Hazards in the atmospheric or aquatic environment are presented in Tables 4-14 and 4-15.

4.4.1 Atmospheric Concerns

In general, atmospheric emissions do not appear to pose significant hazards to public health.

As shown in Table 4-14 none of the constituents in the utility stack gas, cooling tower atmospheric losses or lockhopper vent gas fall into the Probable Hazard category. The lockhopper vent gas is the only one of these streams which is unique to Lurgi/Fischer-Tropsch. The other two streams are found in many other industrial applications, including electricity generation.

Possible Hazards include trace elements, sulfur oxides, nitrogen oxides, ammonia, hydrogen sulfide, nickel carbonyl, fatty acids, phenols and mercaptans.

TABLE 4-14

POLLUTANTS PROJECTED TO BE PROBABLE OR POSSIBLE HAZARDS IN THE ATMOSPHERIC ENVIRONMENT

Substance	Primary Emission Source	Standard
PROBABLE HAZARDS		
None		
POSSIBLE HAZARDS		
Trace Elements		
Arsenic	cooling tower evaporation & utility stack gas	EPC
Mercury	utility stack gas	EPC
Gases		
Hydrogen sulfide	lockhopper vent gas	EPC
Nitrogen oxides	utility stack gas	NAAQS
Sulfur dioxide	utility stack gas	NAAQS
Nickel carbonyl	lockhopper vent gas	EPC
Ammonia	cooling tower evaporation & lockhopper vent gas	EPC

TABLE 4-15

POLLUTANTS PROJECTED TO BE PROBABLE OR POSSIBLE HAZARDS IN THE AQUATIC ENVIRONMENT

Substance	Primary Effluent	Standard*
PROBABLE HAZARDS		
Trace Elements		
Beryllium	Reverse osmosis	EPC
Nickel	Reverse osmosis, combined ash leachate	EPC
Phenols		
Catechol	Reverse osmosis	DWS
3,6-Dimethylcatechol	Reverse osmosis	DWS
4-Methylcatechol	Reverse osmosis	DWS
2-Methylphenol	Reverse osmosis	DWS
3-Methylphenol	Reverse osmosis	DWS
4-Methylphenol	Reverse osmosis	DWS
4-Methylresorcinol	Reverse osmosis	DWS
5-Methylresorcinol	Reverse osmosis	DWS
Resorcinol	Reverse osmosis	DWS
2,4-Xylenol	Reverse osmosis	DWS
3,5-Xylenol	Reverse osmosis	DWS
Mercaptans		
Methanethiol	Reverse osmosis	DWS
POSSIBLE HAZARDS		
Trace Elements		
Aluminum	Combined ash leachate	EPC
Arsenic	Reverse osmosis	DWS
Boron	Reverse osmosis	EPC
Cadmium	Reverse osmosis	DWS
Lead	Reverse osmosis, combined ash leachate	DWS
Mercury	Reverse osmosis	DWS
Selenium	Combined ash leachate	DWS
Vanadium	Reverse osmosis	EPC

*EPC = EPA's Estimated Permissible Concentration for Health;
DWS = EPA's Drinking Water Standard.

TABLE 4-15 (Concluded)

Substance	Primary Effluent	Standard*
Aliphatics, Alicyclics, and Fatty Acids		
Acetic acid	Reverse osmosis	EPC
Hexanoic acid	Reverse osmosis	EPC
Pentanoic acid	Reverse osmosis	EPC
Substituted Benzenes		
Toluene	Reverse osmosis	EPC
Polynuclear Aromatic Hydrocarbons		
Biphenyl	Reverse osmosis	EPC
Indan	Reverse osmosis	EPC
Napthalene	Reverse osmosis	EPC
Aromatic Amines		
Aniline	Reverse osmosis	EPC

Trace elements are a Possible Hazard in all three quantified atmospheric streams, and also are present in several unquantified atmospheric emission streams. Arsenic and mercury in particular have been identified. These elements are toxic under acute and chronic exposure and, as compounds, are considered carcinogenic. Arsenic can damage the kidney and liver, and inhibit enzyme activity. Mercury exposure can result in neural, renal, and cardiovascular disorders. The hazards they pose are aggravated by the fact that trace elements do not biodegrade in the environment and both arsenic and mercury have relatively long biological half lives once they are absorbed into the body. Both metals are known to bioaccumulate as they are transferred through food chains. As a result it appears that trace elements may pose public health hazards to exposed populations near Lurgi/Fischer-Tropsch facilities.

Sulfur oxides are respiratory irritants that can instigate tissue dysfunction as well as exacerbate existing respiratory disorders. Nitrous oxides primarily effect the lungs, although the liver, kidney, and cardiovascular systems may also be adversely affected. Although projected ambient sulfur oxide and nitrogen oxide levels are in the Possible Hazard category these problems are not from sources unique to Lurgi/Fischer-Tropsch technology. Their primary quantified source is the utility stack gas, Stream 28. Strict emissions control levels have been set for SO_x and NO_x and emissions from coal fired boilers. Additionally a variety of commercially proven technologies exist for removing these compounds from stack gases. As a result of the availability of controls and required emission standards it is unlikely that SO_x or NO_x emissions will result in ambient concentrations that exceed standards in commercial scale Lurgi/Fischer-Tropsch facilities.

Ammonia from cooling tower atmospheric losses, Stream 29, and lockhopper vent gas, Stream 72, is a Possible Hazard. Ammonia is an irritant to the eyes and respiratory tract. However ammonia is not expected to be a significant public health concern because: 1) it degrades readily in the atmosphere, 2) there is no evidence that low level exposure has chronic effects, and 3) many commercially proven technologies exist for removing ammonia from aqueous streams, e.g., cooling tower water.

Hydrogen sulfide, fatty acids, phenols, and mercaptans are Possible Hazards from Stream 72, the lockhopper vent gas. Under normal operations this stream will be flared. This should reduce the projected post-dilution concentrations of the organics considerably. Thus fatty acids, phenols, and mercaptans should not be risks to public health from Lurgi/Fischer-Tropsch technologies. Hydrogen sulfide may remain a problem even if the lockhopper vent gas is flared. Because hydrogen sulfide is a respiratory irritant at low concentrations and a rapid acting, acute toxin at levels above 400 ppm, it must be considered a potential hazard to public health. However, its relatively short biological half-life (approximately 20 minutes) under ambient atmospheric conditions; and its easily detected odor at high concentrations, tend to lessen the public health hazards associated with this process stream.

Nickel carbonyl is a proven carcinogen under chronic exposure conditions in occupational environments. Under acute exposure conditions it may induce chemical pneumonitis. It is present in the lockhopper vent gas and may be present in currently unquantifiable streams; therefore, it represents a potential concern to human health in the vicinity of the plant.

4.4.2 Aquatic Concerns

Aqueous discharges from a Lurgi/Fischer-Tropsch facility may contaminate groundwater and pose risks to public health. Streams of concern include: reverse osmosis waste solution (Stream 53), leachate from gasifiers and utility ashes (Stream 69), and leachate from biosludge (Stream 71). Classes of stream constituents which have been screened as Probable Hazards and Possible Hazards for Stream 53 and 69 are presented in Table 4-15. Biosludge leachate has not been considered in the public health analysis due to lack of characterization data. But it could be expected to contain trace elements and organic compounds associated with the reverse osmosis waste.

The analysis of aqueous discharges and leachates indicates that three chemical groups (trace elements, phenols, and mercaptans) contain constituents projected to be Probable Hazards. Four chemical groups (trace elements, fatty acids, substituted benzenes, and polynuclear aromatic hydrocarbons) contain Possible Hazards.

Beryllium and nickel are projected to be Probable Hazards in the reverse osmosis waste where they exceed their EPC_{WH} by factors of 12 and 11, respectively. The toxic effects of beryllium are due almost exclusively to inhalation. Chronic inhalation may cause berylliosis. Beryllium is known to cause cancer in animals. Several nickel compounds also exhibit carcinogenic properties; however, both beryllium and nickel may be considered as part of the general trace element concern. Other trace elements categorized as Possible Hazards include: aluminum, arsenic, boron, cadmium, lead, mercury, selenium and vanadium. Trace elements projected to violate or nearly violate Multi-Media Environmental Goals (MEG's) and Drinking Water Standards include As, Be, Cd, Hg, Ni, Pb, Se, and V. The toxicity of trace elements in aqueous conditions varies significantly with the chemical form of the element. In general the free ion states of the elements are most toxic. The degree to which trace elements attenuate in natural systems is also a function of chemical form. Once again the ionic form of the trace element is the most reactive and most likely to adsorb to particles or other substances in the solution or transfer medium, where it becomes much less available for subsequent toxic impact. Some trace elements may be altered in chemical form by biological systems that are more toxic than the original form (e.g., Hg methylmercury). The long biological half life of trace elements makes the potential for accumulations of toxic quantities in human receptors a potential effect of low level exposures.

The presence of trace elements in each aqueous discharge is additive to several atmospheric emissions. Because of their toxicity, non-degradability and relatively long biological half-lives, trace elements may pose a significant concern to public health. Based on results of the screening process and body burden calculation, arsenic, beryllium and lead appear to pose the greater hazards.

All of the phenolic compounds considered in the study were identified as Probable Hazards, based on their Post-dilution Concentration/Safe Drinking Water Standards. However the Safe Drinking Water Standards for phenols are based on organoleptic qualities of phenol, not toxic properties. As such it is likely that risks to public health are considerably lower than are indicated by the Post-dilution Concentration/Safe Drinking Water Standard ratios.

For example the ratios of the Post-dilution Concentration to EPC_{WH} (based on toxicity) are generally two to three orders of magnitude lower than the Post-dilution Concentration/Safe Drinking Water Standard ratios, indicating that phenols should be classified as Possible Hazards rather than Probable Hazards. Additionally, a variety of commercially proven technologies exist to remove phenol from aqueous waste streams. The presence of phenolic compounds in presently unquantified aqueous discharges, however, may aggravate risks to public health. Potential toxic effects of phenols include kidney and liver damage due to exposure and suspected synergistic reactions with some carcinogens (e.g., coal tars).

The Post-dilution Concentrations of methanethiol resulting from discharge of the reverse osmosis stream (Stream 53) exceeds the EPC_{WH} by a factor of 42. It is also found in eight Lurgi/Fischer-Tropsch streams which are currently unquantifiable. The primary toxic effects from methanethiol results from respiratory paralysis and pulmonary edema. Methanethiol may present a significant concern to public health.

Fatty acids from Stream 53 are monocarboxylic and widely distributed in nature. The toxic effects are not cummulative. Fatty acids rapidly biodegrade in aquatic systems and can be removed from drinking water through conventional treatment methods. Thus, fatty acids released in facility streams do not pose a significant public health concern.

Substituted benzenes from Stream 53 (including toluene, indan and biphenyl) constitute a Possible Hazard. Toluene may be inhaled, ingested or absorbed through the skin. It affects the central nervous system, liver, kidneys and skin. The effects of toluene inhalation on workers subjected to chronic exposure of toluene vapor include decreased phagocytic activity of leukocytes, depression of the central nervous system, narcosis, addiction and even death at high levels. However, toluene undergoes rapid photochemical degradation and it has a short biological half life. It probably does not present a significant risk. There are no documented effects from biphenyl and no toxic information on indan. Indan has been found in coal tar pitch which has been shown to produce cancerous tumors in man. In general, benzenes and substituted benzenes probably do not represent significant concerns to public health, but the inadequacy of the toxicologic data base warrants more research.

The risks posed by polynuclear aromatic hydrocarbons in Stream 53 are difficult to assess. Naphthalene is the only member of the class which is classified as a Possible Hazard. However the lack of toxicologic benchmarks for many of the polynuclear aromatic compounds introduces too much uncertainty to allow generalizations for the class as a whole.

The high degree of uncertainty, coupled with the presence of polynuclear aromatic hydrocarbons in presently unquantified facility streams and the adverse environmental characteristics (biorefactory, bioaccumulative and carcinogenic) of some of these compounds indicate that they must be considered to pose a significant concern, at least until more data become available.

4.4.3 Substance of Concern

To conclude this analysis, two lists of toxic substances from Lurgi/Fischer-Tropsch liquefaction are presented. The first list, Table 4-16 includes the substances that have been quantified in Lurgi effluents. Sufficient data for these substances are avilable to compare the health risks from coal liquefaction wastes to those from other sources of the same pollutants. Public health impacts from Lurgi/Fischer-Tropsch production of these substances are severe enough to warrant investigating environmental controls beyond those of the reference system. The second list, Table 4-17, is a qualitative assessment and includes substances that may be released in Lurgi effluents but have not been quantified and are highly toxic. These pollutants may be on the Cancer Assessment Group list of carcinogens or included in Cateogry C (see Sec. 4.2). Thus the inherent potential for health impact of these substances, if released, is great enough to warrant further characterization.

TABLE 4-16

SUBSTANCES OF CONCERN -- QUANTITATIVE ANALYSIS

Trace Elements

- Arsenic
- Boron
- Beryllium
- Cadmium
- Mercury
- Nickel
- Lead
- Selenium
- Vanadium

Polynuclear Aromatics

- Biphenyl
- Napthalene
- Indan

Gases

- Nickel carbonyl

Phenols

- Catechol
- 3,6-Dimethylcatechol
- 3-Methylcatechol
- 4-Methylcatechol
- 2-Methylphenol
- 3-Methylphenol
- 4-Methylphenol
- 4-Methylresorcinol
- 5-Methylresorcinol
- Phenol
- Resorcinol
- 2,4-Xylenol
- 3,5-Xylenol

Sulfur Heterocyclics

- Methanethiol

TABLE 4-17

SUBSTANCES OF CONCERN -- QUALITATIVE ANALYSIS

Benzenes and Substituted Benzenes

- Ethylbenzene
- Xylene
- Benzene*

Polynuclear Aromatic Hydrocarbons

- Anthracene*
- Fluoranthene
- Fluorene
- Napthalene
- Phenanthrene
- Pyrene
- Indene
- Biphenyl
- Chrysene*
- Benzo(a)pyrene*

Phenols

- Xylenol*

Oxygen Heterocyclics

- Benzofuran
- Dibenzofuran

Nitrosamines

- N-nitrosamine

Nitrogen Heterocyclics

- Acridine

Gases

- Nickel carbonyl*

Trace Elements

- Arsenic
- Beryllium*
- Cadmium*
- Lead
- Mercury
- Chromium*
- Nickel*
- Sulfur*
- Vanadium
- Uranium
- Cobalt
- Barium

*Carcinogens

5 OCCUPATIONAL HEALTH ASSESSMENT

5.1 INTRODUCTION

The operation of future coal liquefaction facilities may create potentially significant health and safety hazards for the occupational personnel. While it is not possible to assess adequately the health impacts of the liquefaction industry in this pre-operational study, available data have been used to estimate hazards and identify pertinent gaps in knowledge. This chapter presents an initial evaluation of possible occupational health hazards, and describes the research necessary for a more complete health assessment of this technology.

The uncertainty as to the potential kinds and quantities of chemicals produced by liquefaction processes and uncertainty regarding the biological effects of potential emissions, preclude the use of sophisticated, quantitative assessment methodologies. The major uncertainty in assessment science is the lack of any "accepted" methodology for deriving limiting exposures for compounds and especially for complex mixtures. A crucial problem is interpretation and extrapolation of the results of short-term toxicity tests for complex mixtures (perhaps relative to pure compounds) to provide limiting, human-exposure guidance.

Previous studies utilizing a "hazard index" approach have focused upon a pre-operational health assessment of a Foster-Wheeler/Stoic low-Btu gasifier[129], and upon an assessment of environmental parameters of small-scale, fixed-bed, coal gasifiers.[51] In the present study, the hazard index approach is adapted to provide a preliminary assessment of a particular coal liquefaction process (Lurgi/Fischer-Tropsch). Based upon this assessment, some significant health and safety concerns may be anticipated unless appropriate measures are taken.

Occupational health hazards from Lurgi/Fischer-Tropsch liquefaction stem primarily from exposures to toxic substances. Both the general public and specific occupational groups may be subject to such hazards, but individual occupational hazards are expected to be much greater, although fewer numbers of individuals are involved.

Occupational exposures will result primarily from process stream leaks, accidental spills, waste disposal, and maintenance operations. The following discussion will focus upon the problems of fugitive emissions and leaks; however, a later review of research needs will indicate the necessity for a more detailed analysis of some other sources and types of risk, for example, leachates from ash and other by-products.

5.2 METHODOLOGY

Assessment of occupational health hazards required evaluation of the two major components of risk: the hazards posed by the toxicity of stream constituents, and the exposure of occupational personnel to these hazardous stream constituents.

The assessment of occupational health hazards was accomplished in several steps as shown in Figure 5-1.

The first step in the analysis was to identify classes of compounds which may be present in Lurgi/Fischer-Tropsch facility streams. Identification of classes of potential stream constituents was accomplished through review of literature regarding chemical characterization of streams from Lurgi/Fischer-Tropsch facilities, other indirect liquefaction processes, and gasification processes. Several classes of compounds were selected for inclusion in this analysis based upon their association with gasification and liquefaction processes and their potential for adverse effects on human health (Table 5-1). Initially all of the gaseous facility streams identified in the plant block flow diagram (Figure 2-1) were considered for analysis because they all contain toxic materials.

The second step was identification of facility streams which may result in exposure of occupational personnel to toxic substances identified in step 1. Unlike the assessments of public health risks and ecosystem risks which emphasized facility streams released to the environment under normal operating conditions, the assessment of occupational health risks also considered (and emphasized) internal

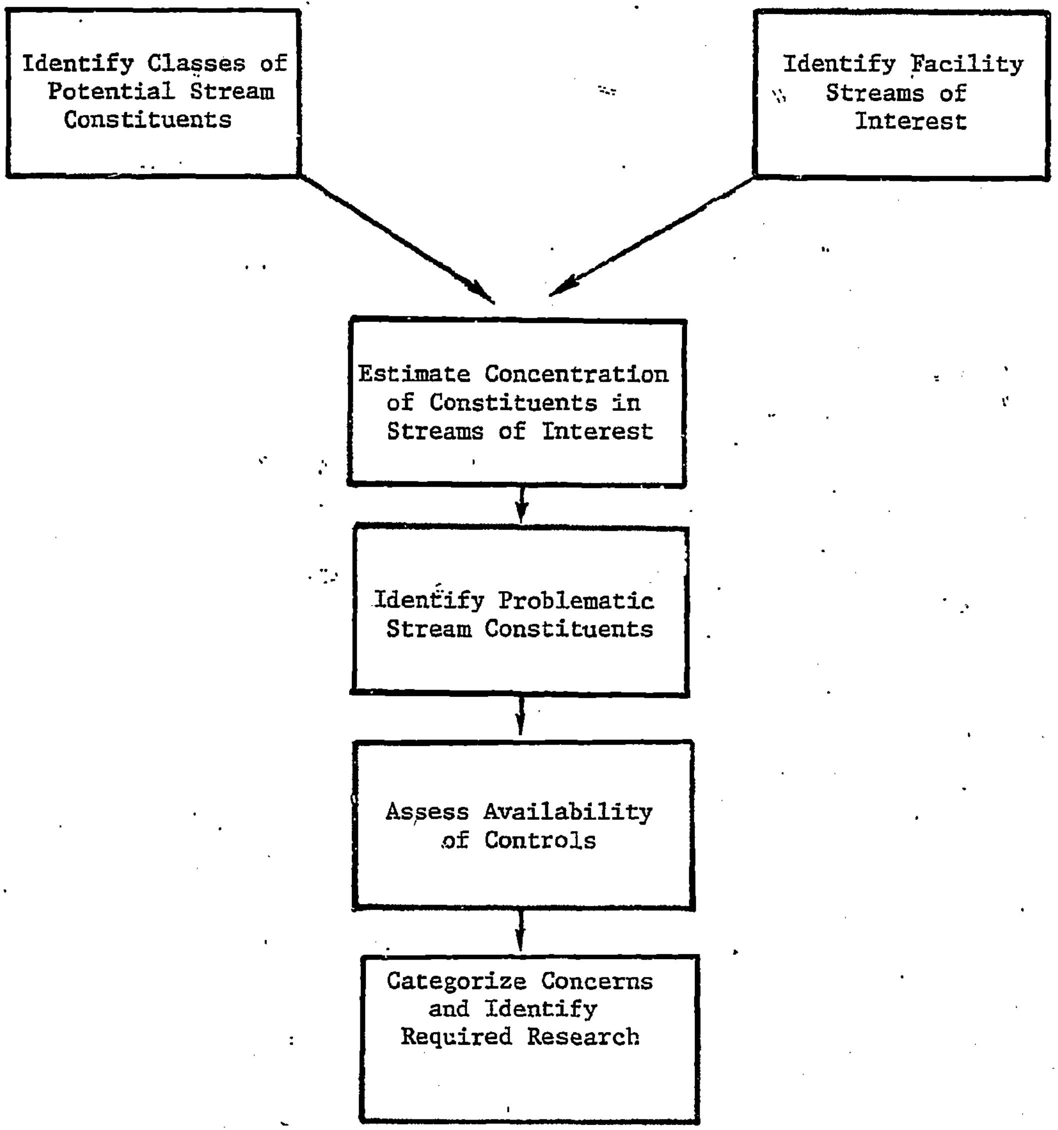


FIGURE 5-1

MAJOR STEPS IN METHODOLOGY TO ASSESS OCCUPATIONAL RISKS process streams which could release toxic substances due to leaks, fugitive emissions, spills and other non-routine events.

The concentrations of the various constituents identified in step 1 were estimated for each stream in step 2.

TABLE 5-1

POTENTIAL STREAM CONSTITUENTS CONSIDERED
IN ASSESSING OCCUPATIONAL HEALTH RISKS

Aromatic Amines	Nitrogen oxides
Carbon monoxide	Nitrosamines
Carbonyl sulfide	Particulates
Ethane	Phenols
Hydrogen cyanide	Polynuclear aromatics
Hydrogen sulfide	Sulfur oxides
Mercaptans	Tars and oils
Methane	Thiophenes
Nickel carbonyl	Trace elements

Problematic stream constituents were identified by using the 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 were compared with their appropriate threshold limit values (TLV). The process stream concentration to TLV ratio was computed for each constituent and then compared with a similarly derived ratio for an "indicator compound" (reference agent). The "indicator compound" is a process stream constituent which has been frequently monitored in the workroom environment as part of standard industrial hygiene programs. The relative differences between the reference agent ratio and the ratios for other gaseous, toxic, stream constituents then were used to identify the potentially hazardous constituents that may be present, but undetected in the workroom air. Thus, certain materials such as carbon monoxide (CO) may become "indicator" agents because of their great abundance in the process stream or because of high toxicity (i.e., a low TLV). This method was selected for the present study because: (1) potential hazards could be evaluated without requiring specific details of leakage rates, room volumes, air flow rates, etc.; and (2) indicator compounds could be specified whose concentrations, if kept less than or equal to a fraction of their TLVs in the workroom, should insure that other hazardous compounds in the same streams will be below their TLVs. However, the use of this approach also imposed several limitations: absolute health risks could not be determined, compounds without TLV's could not be addressed, non gaseous constituents could not be evaluated and risks associated with interaction between compounds had to be neglected. Adequate methodologies currently do not exist to evaluate these factors. Calculations were made only for inhalation exposures to compounds. Worst-case scenarios were assumed in which all compounds were considered vaporized upon release from process streams.

Although actual leak rates can be determined only during operation it was assumed that the levels of toxic materials in actual practice will be controlled such that their concentrations in workplace air will not exceed appropriate TLVs. Thus, the restriction is

$$\frac{C_R}{TLV} < 1, \tag{1}$$

where C_R is the concentration of the toxic material in the air. The equation governing the total mass of a material in the air volume available to a worker is

$$\frac{dM_R}{dt} = Pg_f - M_R \lambda , \tag{2}$$

where M_R = mass of material in workplace air,
P = fraction leaking into workplace air,
g_f = toxic material mass flow rate in the process stream,
λ = turnover rate of air in the work location.

The solution of Equation (2) is

$$M_R = \frac{Pg_f}{\lambda} (1 - e^{-\lambda t}) . \tag{3}$$

For sufficiently long times, such as 8 hours, Equation (3) is closely approximated by

$$M_R = \frac{Pg_f}{\lambda} \quad . \tag{4}$$

From Equation (4) the leak rate that results in a buildup of material, M_R, in the workplace air is

$$P = \frac{M_R \lambda}{g_f} \quad . \tag{5}$$

Equations (5) and (1) were used to calculate allowable leak rates for each agent (assuming other agents are absent) which would present the strictest requirements in terms of leak control. Leak rates relative to CO were calculated in order to determine whether CO may be a suitable indicator compound. Therefore, P_i/P_{CO} is calculated, where P_i is the allowable leak rate for toxic material "i" and P_{CO} is the allowable leak rate for CO.

With C_R replaced by the TLV in the limiting case, and given that $M_R = C_RV_R$, where V_R is the air volume, and $g_f = C_pv_p$, where C_p is the concentration of the toxic material in the process stream, and v_p is the volume flow rate of the process stream, the following equation is derived:

$$\frac{P_i}{P_{CO}} = \frac{TLV_iC_{p,CO}}{TLV_{CO}C_{p,i}} \quad . \tag{6}$$

If P_i/P_{CO} is greater than 1, then the concentration of toxic material, "i", will not exceed its TLV if the TLV of CO is not exceeded. The magnitude of the ratio will indicate how much below or above the TLV the concentration of material, "i", would be, given that CO does not exceed its TLV.

The availability of controls for problematic compounds was then assessed. Those problematic compounds for which controls are available were assessed no further. Those constituents for which controls are not well advanced were assessed by comparing allowable leak rates with leak rates in typical refinery operations.

In the final step, occupational concerns were categorized, and gaps in knowledge and research needs were identified.

In addition to the problematic gaseous constituents, there are several non-gaseous constituents that are of particular importance in the assessment of potential health hazards to occupational personnel. Because an adequate methodology does not exist to assess those constituents, they have been addressed only briefly and qualitatively.

5.3. SELECTION OF INDICATOR COMPOUNDS

Guidance for control of occupational exposures in coal liquefaction is expected to derive from experience with other coal technologies supplemented by continuous monitoring of occupational exposures and employee health. Carbon monoxide is one candidate for an indicator compound because it occurs in relatively high concentrations in several process streams and sensitive, multipoint, continuous monitoring systems are commercially available. Given the ranges from which mean estimates in Table 5-2 were derived and the TLVs for occupational exposures, CO has been determined to be an acceptable indicator compound for most streams. Of course, CO may not be acceptable as an indicator during maintenance, spill cleanup or high temperature release of tars, oils, and other liquids under pressure.

Preliminary calculations also indicate that phenols may be used as the "indicator" if measuring techniques of adequate sensitivity can be developed. Again, however, phenols cannot be used to indicate hazards from leakage of tars and oils.

5.4 RESULTS

The ratios of the allowable leak rates relative to CO are given in Table 5-2 for typical and worst-case streams. Based upon these results, it appears that CO is a good indicator for most potential hazards in streams in which CO is present. Exceptions are: (1) CO_2 in Streams 55, 56, 66, and 68, (2) CH_4 in Stream 18, (3) H_2S in Stream 66, (4) $Ni(CO)_4$ in Stream 18, and (5) tars and oils in all streams in which

TABLE 5-2

RELATIVE ALLOWABLE LEAK RATES FOR THE TOXIC MATERIALS IN STREAMS CONTAINING CO

Component	TLV		Typical Stream[a]	Allowable Leak Rate, Relative to CO	Worst Stream[a]	Allowable Leak Rate, Relative to CO
	ppm	mg/m^3				
Gases						
CO	35	40	7	1	7	1
CO_2	5,000		7	91	66	0.6
CH_4	5,000		7	240	18	0.1
Ethene	5,000		7	36,000	18	10
Ethane	5,000		7	5,000	18	4
H_2S	10		7	10	66	0.29
SO_2	5		51	5	51	9.6
Liquids[b]						
Methanol		260	16	17,000	16	17,000
Tar		0.1[c]	7	0.04	7	0.04
Oil			7	0.03	7	0.03
Naphtha		50	7	47.7	13	14.4
Crude Phenols		19	7	18.6	9	18.2
Mercaptans		1	7	363	13	418
Thiophenes		4.5	7	2,039	8	1,988
Ammonia		18	7	27.2	8	26.5
HCN		11	7	20,000	13	9,200
Aromatic amines		19	7	69,000	13	16,000
Nitrosamine		65	7	470,000	13	54,000
Polynuclear aromatic hydrocarbons		0.2	7	36.3	8	35.4
Fatty acids		1	7	5.2	8	5.1
$Ni(CO)_4$		0.43	7	156	18	3.9
Coal		2	7			
Particulates		10	7	36.3	8	35.4
Trace elements Beryllium[d]		0.002	7	3.6	13	1.7
Propene		8,600	17	93	18	10.2
Propane		9,000	17	556	18	106
Butene		9,140	17	138	17	138
Butane		1,400	17	165	17	165
Pentene		350	17	7.3	17	7.3
Pentane		350	17	55	17	55
Hexene		350	17	9.2	17	9.2
Hexane		350	17	53	17	53
C+7 Hydrocarbons		350[e]	17	1.3	17	1.3

[a] See Table 3.1, Fig. 3.1 for stream identification.

[b] Considers worst possible case, in which liquids totally vaporize upon release.

[c] Assumed to be the same as the NIOSH recommended standard for coal-tar products.

[d] Assumes all trace elements are beryllium, which has the lowest TLV.

[e] Assumed.

they are present. However, technology for handling CO_2 and CH_4 are available (e.g., LP bottled gas) and their effects are already accepted; therefore, they are not considered to present an unacceptable risk. Exposures to $Ni(CO)_4$ and H_2S from leaks or spills from Stream 18 are thought to be controllable by limiting the CO concentration around this stream to 1/3 of the TLV for CO, or using local ventilation around this stream to remove these vapors from the area occupied by workers. Health effects might occur from leakage of tars and oils from certain of the process streams (7-17) because these streams are at elevated temperatures and pressures, increasing the potential for leaks, and CO does not effectively serve as an indicator compound for monitoring these compounds.

To determine whether or not current technology exists to prevent assumed TLV's for tar and oil from being exceeded, process-stream leak rates resulting in TLV concentrations were estimated using worst-case assumptions that approach "worst-case" conditions. There leak rates were compared with leak rates typical of refinery operations. These assumptions include: (1) all tars and oils totally vaporize upon release from process streams to the work environment; (2) exposed workers are confined to 10m X 10m X 2m volumes around leaks; (3) air turnover rates for worker volumes are 1 volume turnover per hour. From Equation (4),

$$M_R = \frac{Pg_f}{\lambda} . \qquad (4)$$

Dividing by V_R, the worker volume,

$$C_R = \frac{Pgf}{V_R} . \qquad (7)$$

But, g_f is:

$$g_f = C_s \cdot V_s , \qquad (8)$$

where V_s is the process stream flow rate (volume/time) and C_s is the concentration (mass/volume) of the material in the process stream. By definition:

$$P = \frac{V_e}{V_s} \qquad (9)$$

where V_e is the leak rate from the process stream. Substituting (8) and (9) for (7) gives:

$$C_R = \frac{C_s V_e}{V_R} \tag{10}$$

For the worst-case assumption that all tars and oils are in the gas phase, concentrations in one process stream (No. 7 in Table 5-2) were estimated to be 8.9×10^{-2} gm/l for tar and 1.3×10^{-1} gm/l for oil. Process stream leak rates giving TLV concentrations are 2.2×10^{-4} m^3/hr for tar and 1.5×10^{-4} m^3/hr for oil. Light liquid/two phase valves and flanges at refineries leak at average rates of 0.02 and 0.0056 lb/hr/source, respectively.[115] Assuming one leaking valve and five leaking flanges in Stream 7 of a liquefaction plant, the leak rate from Stream 7 might be expected to be 0.027 lb/hr. Oils have molecular weights ranging from 300-500 gms/gm-mole. The average molecular weight of the gas in Stream 7 was then estimated as 20 gm/gm-mole. Using this value, process stream leak rates giving TLV concentrations in the work area for worst case assumptions are 0.0048 lb/hr for tar and 0.0033 lb/hr for oil. Therefore, leaks from Stream 7 are approximately 5 times more than adequate to result in TLV concentrations.

This calculation indicates that the concern for inhalation of tars and oils, though real, is not excessive. In the calculation, concentrations of tars and oils have been grossly overestimated in the work area. First, oils and tars were assumed to vaporize upon release to the work area. Most substances cool upon expansion; therefore, the tar and oil should cool upon release to the work area, and much of the tar and oil is expected to remain as liquid and not as vapor. Second, the worker was restricted to a very small area around the leak. The air volume exchange in the worker area was low at 1 change/hr. Third, leaks from process streams would be expected to discriminate against higher-molecular-weight molecules. Thus, a higher leak rate would be necessary to reach TLV concentrations.

5.5 DISCUSSION

Operation of a coal liquefaction facility may present the potential for significant risk to human health in an occupational setting. A large number of compounds are of concern. Perhaps of greatest concern are the tars and oils from the gasifier which contain high concentrations of polynuclear aromatic hydrocarbons, heterocyclic compounds, and trace elements. Based upon the use of CO as an indicator compound within the workroom environment, and using the hazard category definitions listed in Table 5-3, tars and oils represent the only Probable Hazards. Carbon dioxide, methane, represent possible hazards from one or more process streams. The emissions of nickel carbonyl from Stream 18 (SNG) and hydrogen sulfide from Stream 66 (stack gas from Fischer-Tropsch heaters) also may pose problems.

TABLE 5-3

DEFINITION OF HAZARD CATEGORIES FOR
OCCUPATIONAL HEALTH ASSESSMENT

Probable Hazard	Allowable Leak Rate Relative to CO <0.1
Possible Hazard	Allowable Leak Rate Relative to CO $\geq$0.1 but <1.0
Unlikely Hazard	Allowable Leak Rate Relative to CO $\geq$1.0

For leaks from process streams containing CO, regulation of CO by the TLV level may be sufficient to ensure that other potentially hazardous chemicals will be adequately regulated for the majority of chemicals and process streams. The most notable exception to the above statement is the case of tars and oils, which may not necessarily be below appropriate TLV levels, even if CO is thus regulated. In addition, tars and oils pose carcinogenic hazards both by inhalation and dermal contact. Dermal exposure could arise from operating valves, during maintenance, exposure to leaks in pipes, etc. Careful adherence to a comprehensive industrial hygiene program should be maintained with emphasis on protective clothing, periodic physical examination, and documentation of accidental skin exposures. Leaks from a few process streams may result in levels of CO_2, CH_4, H_2S and trace metals above their respective TLVs even if CO is adequately controlled. In most of these cases (CH_4 is the exception), if CO is regulated to a concentration somewhat below its TLV level (approximately 1/2 to 1/5) these other compounds will be controlled adequately. This is not an unreasonable level of control, considering the worst-case assumptions made in deriving these numbers, and should be technically achievable.

A calculation based on leak rates from oil refinery operations suggests that tars and oils may be 5 times their TLVs (assuming total vaporization of such materials from any leak and that workers are exposed in an enclosed area around this leak). These assumptions are clearly worst-case, and if the facility is open to the atmosphere and tars and oils condense to any reasonable extent (as it seems likely they will), oil and tar concentrations will probably be below TLVs.

Dermal exposure of workers to tars and oils and other process stream condensates during routine operation, maintenance, etc. may pose significant potential for skin carcinogenesis, and possibly other health hazards. This problem can best be addressed by adequate protective clothing, worker education, a vigorous program of industrial hygiene, and worker monitoring by periodic examinations. No existing methodology was considered adequate for quantifying dermal exposures.

It is extremely difficult to address potential problems in a specific manner in a preoperational assessment. This is due to the large uncertainties associated with factors such as concentration of various toxicants in process streams, leak rates of these various streams, the probability of in-plant personnel being in regions where leaks are occurring, and the method of disposal of various waste products, etc. Estimation of the concentrations of chemicals in various process streams by comparison with other liquefaction processes and plants (such as SASOL in South Africa)[165] is not satisfactory for specific health risk analysis either; toxicants in process streams may vary (depending on the starting coal composition and the specific liquefaction process), design of process stream plumbing may vary (hence the points at which maximal leakage may occur could differ significantly), and positioning of worker stations may vary.

In Volume V additional research is described which, if implemented, will improve the present tentative statements concerning health risk analysis of this coal liquefaction assessment.

6 CONCLUSIONS

6.1 OVERVIEW

The results of the ecological, public health, and occupational health assessments have been described briefly in Chapters 3, 4 and 5, respectively. Several process and waste streams have been evaluated, and numerous chemical constituents have been categorized. In the preceding chapters the results have been presented and discussed separately in terms of individual receptor groups. The purpose of this chapter is to integrate the results across receptor populations to estimate the relative hazards posed by facility streams and classes of stream constituents.

It is extremely difficult to address potential problems in a specific manner in a preoperational assessment. A number of factors which could have a significant impact on the type, magnitude and severity of hazards posed by the hypothetical plant have not been evaluated in the assessment due to lack of data. These factors are described in detail in Volumes II, III, IV and V of this reports, and have been summarized in the previous chapter of Volume I. Because these factors have not been considered, the uncertainty regarding the results of the assessment is substantial, and should be considered in reviewing or utilizing the assessment results. This uncertainty is further exacerbated by the paucity of toxicologic data for many pollutants, and the lack of specific information regarding potential receptor populations. The results of this study, however, do represent a useful state-of-the-art assessment of the potentially hazardous trace contaminants from a commercial-scale Lurgi/Fischer-Tropsch liquefaction facility.

The potential hazards associated with the operation of a Lurgi/Fischer-Tropsch liquefaction facility will vary among process streams, classes of chemicals, and exposed receptor populations. Section 6.2 of this chapter describes chemical hazards associated with various facility streams. Section 6.3 describes the degree of hazard associated with various chemical classes in all analyzed process and waste streams. Section 6.4 summarizes the major conclusions from sections 6.2 and 6.3.

6.2 CATEGORIZATION OF FACILITY STREAMS BY HAZARD LEVEL

The ecological, public health, and occupational hazards associated with various Lurgi/Fischer-Tropsch process and waste streams have been evaluated. These concerns are summarized for each of six waste streams, in Tables 6-1 and 6-2, and discussed in the following sections. In the summary of the ecological and public health concerns for a particular waste stream, it should be noted that some of these concerns may be mutually exclusive, because different assumptions and scenarios sometimes have been used in the ecological and public health assessments (e.g., the wastes from the reverse osmosis unit have been projected to enter a small surface water stream in the ecological assessment and an isolated groundwater system in the public health assessment).

6.2.1 Utility Stack Gas (Stream 28)

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. Prior to discharge an electrostatic precipitator reduces particulate matter to 0.1 pounds per million Btu of fuel fired; and lime slurry scrubbing reduces SO_2 to 0.2 pounds per million Btu of fired heat.

Although supplemental fuels (i.e., gasifier tars and phenols) and incineration fuel (i.e., sour gases) are used, over 80 percent of the Btu's fired are derived from undersized coal. The stack gas, therefore, may be expected to be similar to stack gas from a coal-fired power plant utilizing Wyoming subbituminous coal. However, because gasifier tar comprises a significant fraction of total Btu fired (i.e., 17%), differences between trace element content of the coal and tar (on a Btu basis) do affect trace element release from the boiler. Calculations based on SASOL distribution coefficients indicate that substitution of

TABLE 6-1 : HAZARD POTENTIAL OF AQUEOUS STREAM CONSTITUENTS*
(Streams 53,69 and 70).

	STREAM 53 - REVERSE OSMOSIS WASTE										STREAM 69 - ASH LEACHATE									STREAM 70 - BIOSLUDGE									
	Public Health		Ecological								Public Health		Ecological							Public Health			Ecological						
	1 EPC	2 DWS	3 LOLC	4 LOTC	5 EPC	6 HTC	7 DCTC	8 TBC	9 PFC	10 AFC	11 EPC	12 DWS	13 EPC	14 LOTC	15 HTC	16 DCTC	17 TBC	18 PFC	19 AFC	20	21	22 LOLC	23 LOTC	24 HTC	25 DCTC	26 TBC	27 PFC	28 EPC	29 AFC
TRACE ELEMENTS																				NOT EVALUATED									
Aluminum											◎	-	○	○	○	○	○	-	○										
Arsenic	-	◎	-	◎	●	○	◎	●	◎	●	-	○	○	○	○	○	○	○	○			●	●	○	◎	●	◎	●	●
Beryllium	●	-	-	◎	●	○	-	○	●	●												◎	◎	○	-	○	●	●	●
Boron	◎	-	-	◎	◎	○	-	○	-	◎																			
Cadmium	-	◎	-	●	●	◎	●	●	●	●	-	○	○	○	○	○	○	○	○			●	●	◎	●	●	●	●	●
Copper											○	-	○	◎	○	○	○	-	○										
Fluorine	-	-	-	◎	-	○	-	-	-	●																			
Iron											-	-	○	○	○	○	○	-	◎										
Lead	-	◎	-	◎	◎	○	◎	◎	◎	◎	-	◎	○	○	○	○	○	○	○			◎	◎	○	◎	●	◎	◎	●
Manganese	-	-	-	○	●	○	○	●	-	◎			○	○	○	○	◎	-	○										
Mercury	-	◎	-	●	●	◎	◎	●	●	●	-	○	○	○	○	○	○	○	○			◎	●	◎	◎	●	●	●	●
Nickel	●	-	-	◎	●	◎	◎	◎	-	●	◎	○	○	○	○	○	○	-	○										
Selenium											-	◎	○	○	○	○	○	○	◎										
Vanadium	◎	-	-	○	○	○	-	○	-	◎																			
Zinc											-	○	○	○	○	○	○	-	○										
TOTAL TRACE ELEMENTS																													
ALIPHATICS, ALICYCLICS AND FATTY ACIDS																													
Acetic Acid	◎	-	○	-	◎	-	-	-	-	-																			
Butanoic Acid	-	-	○	○	-	-	-	-	-	-																			
Hexanoic Acid	◎	-	○	-	○	-	-	-	-	-																			
3-Methylbutanoic Acid	-	-	-	-	-	-	-	-	-	-																			
2-Methylbutanoic Acid	-	-	-	○	-	-	-	-	-	-																			
Pentanoic Acid	◎	-	○	-	○	-	-	-	-	-																			
Propanoic Acid	-	-	○	-	-	-	-	-	-	-																			
TOTAL FATTY ACIDS																													
BENZENES & SUBSTITUTED BENZENES																													
Biphenyl	◎	-	-	-	-	-	-	-	-	-																			
Ethylbenzene	○	-	◎	-	◎	-	-	-	-	-																			
Indan	◎	-	-	-	◎	-	-	-	-	-																			
Toluene	◎	-	◎	◎	◎	-	-	-	-	-																			
1,2,4-Trimethylbenzene																													
o-Xylene	○	-	-	◎	◎	-	-	-	-	-																			

○ UNLIKELY HAZARD: (Post-Dilution)/(Benchmark) ≤ 0.1

◎ POTENTIAL HAZARD: (Post-Dilution)/(Benchmark) > 0.1 but < 10

● PROBABLE HAZARD: (Post-Dilution)/(Benchmark) ≥ 10

\- Constituent identified in Stream but benchmark not available

blank Constituent not identified

Col[illegible] [illegible]adin[illegible] fine[illegible] [illegible]inal

TABLE 6-1 (Continued)

	STREAM 53 - REVERSE OSMOSIS WASTE										STREAM 69 - ASH LEACHATE									STREAM 70 - BIOSLUDGE									
	Public Health		Ecological								Public Health		Ecological							Public Health		Ecological							
	1 EPC	2 DWS	3 LOLC	4 LOTC	5 EPC	6 MTC	7 DCTC	8 TBC	9 PFC	10 AFC	11 EPC	12 DWS	13 EPC	14 LOTC	15 MTC	16 DCTC	17 TBC	18 PFC	19 AFC	20	21	22 LOLC	23 LOTC	24 MTC	25 DCTC	26 TBC	27 PFC	28 EPC	29 AFC
PHENOLS																				NOT EVALUATED									
Catechol	◉	●	◉	◉	●	–	–	–	–	–																			
3,6-Dimethylcatechol	–	●	–	–	–	–	–	–	–	–																			
3-Methylcatechol	–	–	–	–	–	–	–	–	–	–																			
4-Methylcatechol	–	●	–	○	–	–	–	–	–	–																			
2-Methylphenol	○	●	○	○	◉	–	–	–	–	–																			
3-Methylphenol	◉	●	○	○	◉	–	–	–	–	–																			
4-Methylphenol	○	●	○	–	◉	–	–	–	–	–																			
4-Methylresorcinol	–	●	–	–	–	–	–	–	–	–																			
5-Methylresorcinol	–	●	–	–	–	–	–	–	–	–																			
Phenol	◉	●	○	◉	○	–	–	–	–	–																			
Resorcinol	◉	●	◉	–	●	–	–	–	–	–																			
2,4-Xylenol	◉	●	○	–	○	–	–	–	–	–																			
3,5-Xylenol	◉	●	○	○	◉	–	–	–	–	–																			
TOTAL PHENOLS		●			●	–	–	–	–	–																			
POLYNUCLEAR AROMATIC HYDROCARBONS																													
Acenaphthalene	–	–	–	–	–	–	–	–	–	–												–							
Anthracene	–	–	–	○	–	–	–	–	–	–												–	○						
Benz(a)anthracene	○	–	–	○	–	–	–	–	–	–												–	○						
Benzo(g,h,i)perylene	–	–	–	–	–	–	–	–	–	–												–							
Benzo(a)pyrene	○	–	–	–	–	–	–	–	–	–												–							
Benzo(e)pyrene	–	–	–	–	–	–	–	–	–	–												–							
Chrysene	–	–	–	○	–	–	–	–	–	–												–							
Fluoranthene	○	–	–	◉	–	–	–	–	–	–												–	◉				◉		
Fluorene	–	–	–	○	–	–	–	–	–	–												–	○						
Naphthalene	◉	–	◉	●	●	–	–	–	–	–												◉	●	–	–	–	●	–	
Perylene	–	–	–	○	–	–	–	–	–	–													–						
Phenanthrene	○	–	○	◉	–	–	–	–	–	–												○	◉	–	–	–	–	–	–
Pyrene	–	–	–	○	–	–	–	–	–	–												–	○	–	–	–	–	–	–
TOTAL PAH's																													
SULFUR HETEROCYCLICS																													
Methylthiophene																													
Thiophene																													
TOTAL THIOPHENES																													

○ UNLIKELY HAZARD: (Post-Dilution)/(Benchmark) ≤0.1

◉ POTENTIAL HAZARD: (Post-Dilution)/(Benchmark) >0.1 but <10

● PROBABLE HAZARD: (Post-Dilution)/(Benchmark) ≥10

– Constituent identified in Stream but benchmark not available

blank Constituent not identified

* Column headings defined on final page

TABLE 6-1 (Continued)

	STREAM 53 - REVERSE OSMOSIS WASTE										STREAM 69 - ASH LEACHATE									STREAM 70 - BIOSLUDGE									
	Public Health		Ecological								Public Health		Ecological							Public Health		Ecological							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	EPC	DWS	LOLC	LUTC	EPC	HTC	DCTC	TBC	PFC	AFC	EPC	DWS	EPC	LOTC	HTC	DCTC	TBC	PFC	AFC			LOLC	LOTC	HTC	DCTC	TBC	PFC	EPC	AFC
NITROGEN HETEROCYCLICS																				NOT EVALUATED										
2,4-Dimethylpyridine	○	-	-	-	-	-	-	-	-	-																			
2,5-Dimethylpyridine	○	-	-	-	-	-	-	-	-	-																			
2-Methylpyridine	○	-	-	-	-	-	-	-	-	-																			
3-Methylpyridine	○	-	-	-	-	-	-	-	-	-																			
4-Methylpyridine	○	-	-	-	-	-	-	-	-	-																			
Pyridine	○	-	○	○	○	-	-	-	-	-																			
Quinoline	○	-	○	○	○	-	-	-	-	-																			
OXYGEN HETEROCYCLICS																													
Benzofuran																													
Dibenzofuran	-	-	-	-	-	-	-	-	-	-																			
MERCAPTANS																													
Methanethiol	●	-	-	◉	-	-	-	-	-	-																			
TOTAL MERCAPTANS																													
AROMATIC AMINES																													
Aniline	○	-	○	-	○	-	-	-	-	-																			
TOTAL AROMATIC AMINES																													
NITROSAMINES																													
MISCELLANEOUS																													
Ammonia																													
Carbonyl Sulfide																													
Hydrogen Cyanide																													
Hydrogen Sulfide																													
Nickel Carbonyl																													
NO_x																													
Particulates																													
SO_x																													
Tars, Oils, Naphtha																													

○ UNLIKELY HAZARD: (Post-Dilution)/(Benchmark) ≤ 0.1
◉ POTENTIAL HAZARD: (Post-Dilution)/(Benchmark) > 0.1 but < 10
● PROBABLE HAZARD: (Post-Dilution)/(Benchmark) ≥ 10

-	Constituent identified in Stream but benchmark not available
Blank	Constituent not identified
*	Column headings defined on final page

TABLE 6-1 (Concluded)

Column	Abbreviation	Explanation
1	EPC	Estimated Permissible Concentration
2	DWS	Drinking Water Standard
3	LOLC	Lowest Observed LC_{50}
4	LOTC	Lowest Observed Toxic Concentration
5	EPC	Estimated Permissible Concentration
6	MTC	Mean Toxic Concentration
7	DCTC	*Daphnia* Chronic Toxic Concentration
8	TBC	Threshold Bioaccumulation Concentration
9	PFC	Proposed Freshwater Criteria
10	AFC	Ambient Freshwater Concentration
11	EPC	Estimated Permissible Concentration
12	DWS	Drinking Water Standard
13	EPC	Estimated Permissible Concentration
14	LOTC	Lowest Observed Toxic Concentration
15	MTC	Mean Toxic Concentration
16	DCTC	*Daphnia* Chronic Toxic Concentration
17	TBC	Threshold Bioaccumulation Concentration
18	PFC	Proposed Freshwater Criteria
19	AFC	Ambient Freshwater Concentration
20	-	Not Evaluated
21	-	Not Evaluated
22	LOLC	Lowest Observed LC_{50}
23	LOTC	Lowest Observed Toxic Concentration
24	MTC	Mean Toxic Concentration
25	DCTC	*Daphnia* Chronic Toxic Concentration
26	TBC	Threshold Bioaccumulation Concentration
27	PFC	Proposed Freshwater Criteria
28	EPC	Estimated Permissible Concentration
29	AFC	Ambient Freshwater Concentration

TABLE 6-2 : HAZARD POTENTIAL OF ATMOSPHERIC STREAM CONSTITUENTS *
(Streams 28,29 and 72).

	STREAM 28 - UTILITY STACK GAS						STREAM 29 COOLING TOWER ATMOSPHERIC LOSSES				STREAM 72 LOCKHOPPER VENT GAS			
	Public Health		Ecological				Public Health		Ecological		Public Health		Ecological	
	1 EPC$_{AH}$	2 NAAQS	3 HSC	4 LOTC	5 EPC$_{AHE}$	6 AAC	7 EPC$_{AH}$	8 NAAQS	9	10	11 EPC$_{AH}$	12 NAAQS	13 TC	14 EPC$_{AE}$
TRACE ELEMENTS									NOT EVALUATED					
Aluminum														
Arsenic	◉	-	○	-	◉	○	◉	-						
Beryllium	○	-	○	○	◉	◉	○	-						
Boron							-	-						
Cadmium	○	-	○	○	○	◉	○	-						
Copper														
Fluorine														
Iron														
Lead	○	○	○	-	◉	◉	○	○						
Manganese														
Mercury	◉	-	○	○	◉	●	○	-						
Nickel							○	-						
Selenium														
Vanadium							○	-						
Zinc														
TOTAL TRACE ELEMENTS											◉	-	○	
ALIPHATICS, ALICYCLICS AND FATTY ACIDS														
Acetic Acid							○	-						
Butanoic Acid							-	-						
Hexanoic Acid							○	-						
3-Methylbutanoic Acid							-	-						
2-Methylbutanoic Acid							-	-						
Pentanoic Acid							○	-						
Propanoic Acid							-	-						
TOTAL FATTY ACIDS											◉	-	○	
BENZENES & SUBSTITUTED BENZENES														
Biphenyl							○	-						
Ethylbenzene							○	-						
Indan							○	-						
Toluene							○	-						
1,2,4-Trimethylbenzene														
o-Xylene							○	-						

○ UNLIKELY HAZARD: (Post-Dilution)/(Benchmark) ≤ 0.1

◉ POTENTIAL HAZARD: (Post-Dilution)/(Benchmark) > 0.1 but < 10

● PROBABLE HAZARD: [illegible]-Dil[illegible])/(B[illegible]rk) [illegible]

\- Constituent identified in Stream but benchmark not available

blank Constituent not identified

* [illegible] heac[illegible] defi[illegible] [illegible]ge

TABLE 6-2(Continued)

	STREAM 28 - UTILITY STACK GAS						STREAM 29 - COOLING TOWER ATMOSPHERIC LOSSES				STREAM 72 LOCKHOPPER VENT GAS			
	Public Health		Ecological				Public Health		Ecological		Public Health		Ecological	
	1 EPC_{AH}	2 NAAQS	3 HSC	4 LOTC	5 $EPC_{AH,E}$	6 AAC	7 EPC_{AH}	8 NAAQS	9	10	11 EPC_{AH}	12 NAAQS	13 TC	14 EPC_{AE}
PHENOLS														
Catechol							○	-	NOT EVALUATED					
3,6-Dimethylcatechol							-	-						
3-Methylcatechol							-	-						
4-Methylcatechol							-	-						
2-Methylphenol							○	-						
3-Methylphenol							○	-						
4-Methylphenol							○	-						
4-Methylresorcinol							-	-						
5-Methylresorcinol							-	-						
Phenol							○	-						
Resorcinol							○	-						
2,4-Xylenol							○	-						
3,5-Xylenol							○	-						
TOTAL PHENOLS											◉	-	◉	
POLYNUCLEAR AROMATIC HYDROCARBONS														
Acenaphthalene							-	-						
Anthracene							-	-						
Benz(a)anthracene							○	-						
Benzo(g,h,i)perylene							-	-						
Benzo(a)pyrene							○	-						
Benzo(e)pyrene							-	-						
Chrysene							-	-						
Fluoranthene							○	-						
Fluorene							-	-						
Naphthalene							○	-						
Perylene							-	-						
Phenanthrene							○	-						
Pyrene							-	-						
TOTAL PAH's											○	-	○	
SULFUR HETEROCYCLICS														
Methylthiophene														
Thiophene														
TOTAL THIOPHENES											○	-		

○ UNLIKELY HAZARD: (Post-Dilution)/(Benchmark) ≤0.1

◉ POTENTIAL HAZARD: (Post-Dilution)/(Benchmark) >0.1 but < 10

● PROBABLE HAZARD: (Post-Dilution)/(Benchmark) ≥ 10

\- Constituent identified in Stream but benchmark not available

blank Constituent not identified

* Column headings defined on final page

TABLE 6-2 (Continued)

	STREAM 28 -UTILITY STACK GAS						STREAM 29 - COOLING TOWER ATMOSPHERIC LOSSES				STREAM 72 LOCKHOPPER VENT GAS			
	Public Health		Ecological				Public Health		Ecological		Public Health		Ecological	
	1 EPC_{AH}	2 NAAQS	3 HSC	4 LOTC	5 EPC_{AHE}	6 AAC	7 EPC_{AH}	8 NAAQS	9	10	11 EPC_{AH}	12 NAAQS	13 TC	14 EPC_{AL}
NITROGEN HETEROCYCLICS									NOT EVALUATED					
2,4-Dimethylpyridine							○	-						
2,5-Dimethylpyridine							○	-						
2-Methylpyridine							○	-						
3-Methylpyridine							○	-						
4-Methylpyridine							○	-						
Pyridine							○	-						
Quinoline							○	-						
OXYGEN HETEROCYCLICS														
Benzofuran														
Dibenzofuran							-	-						
MERCAPTANS														
Methanethiol							○	-						
TOTAL MERCAPTANS											◉	-	○	
AROMATIC AMINES														
Aniline							○	-						
TOTAL AROMATIC AMINES											○	-	○	
NITROSAMINES											-	-	○	
MISCELLANEOUS														
Ammonia							◉	-			◉	-	○	
Carbonyl Sulfide											○	-	○	
Hydrogen Cyanide											○	-	○	
Hydrogen Sulfide											◉	-	○	
Nickel Carbonyl											◉	-	-	
NO_x	-	◉	◉	◉	-	-								
Particulates														
SO_x	-	◉	◉	◉	-	-								
Tars, Oils, Naphtha											-	-	-	-

○ UNLIKELY HAZARD: (Post-Dilution)/(Benchmark) ≤ 0.1

◉ POTENTIAL HAZARD: (Post-Dilution)/(Benchmark) > 0.1 but < 10

● PROBABLE HAZARD: (Post-Dilution)/(Benchmark) ≥ 10

– Constituent identified in Stream but benchmark not available

blank Constituent not identified

* Column headings defined on final page

TABLE 6-2 (Concluded)

Column	Abbreviation	Explanation
1	EPC_{AH}	Estimated Permissible Concentration in Air for Protection of Human Health
2	NAAQS	National Ambient Air Quality Standard
3	MSC	Most Stringent Criteria
4	LOTC	Lowest Observed Toxic Concentration
5	$EPC_{AH,E}$	Estimated Permissible Concentration in Air for Protection of Human Health, or Ecology
6	AAC	Ambient Air Concentration
7	EPC_{AH}	Estimated Permissible Concentration in Air for Protection of Human Health
8	NAAQS	National Ambient Air Quality Standard
9	-	Not Evaluated
10	-	Not Evaluated
11	EPC_{AH}	Estimated Permissible Concentration in Air for Protection of Human Health
12	NAAQS	National Ambient Air Quality Standard
13	TC	Toxic Concentration
14	EPC_{AE}	Estimated Permissible Concentration in Air for Protection of Ecology

tar for coal to provide 17% of the Btu's to the boiler reduces arsenic (9.5%) and cadmium (14%), but increases beryllium (48%) and mercury (8%). Release rates of lead are approximately equal for combustion of coal and tar.

Comparison of estimated post-dilution concentrations of SO_x, NO_x 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. Arsenic, beryllium, lead, and mercury approach, but do not exceed their respective Estimated Permissible Concentrations for health and ecology. Mercury and beryllium also exceed ambient air concentrations. Cadmium and lead approach, but do not exceed their ambient levels in air. Evaluation of the soil deposition flux for the trace elements indicates that the deposition of As, Be, Cd and Pb would be a small fraction of their natural flux, but mercury poses an ecological hazard deserving the highest research priority.

Estimated post-dilution concentrations of sulfur oxides and nitrogen oxides exceed or approach the public health benchmark (NAAQS) and ecological benchmark (Lowest Observed Toxic Concentration and Most Stringent Criteria, i.e., NAAQS). The reason that SO_2, which is reduced to 0.2 lb/million Btu of fuel fired (one sixth of the federal New Source Performance standard), exceeds the NAAQS appears to be that the post-dilution concentrations of both SO_x and NO_x were estimated using dilution factors from the SAM/I model, and therefore, represent maximum ground-level concentrations, not ambient concentrations for an airshed. The potential hazards posed by SO_x and NO_x, therefore, are probably not as significant as indicated by the assessment, and/or they probably would be confined to a very limited area.

6.2.2 Cooling Tower Atmospheric Losses (Stream 29).

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.

Partitioning of contaminants between the vapor phase and liquid droplet phase (drift) may be a critical consideration in determining the dispersion, settling and effects of pollutants, but cannot be determined quantitatively. On the basis of physical properties (e.g., volatility, solubility), trace elements and polynuclear aromatic hydrocarbons may be expected to concentrate in the drift, while phenols and low molecular weight heterocyclics may be in the vapor phase.

In assessing hazards to public health, all cooling towers losses are assumed to be in the vapor form. Comparison of estimated post-dilution concentrations with health benchmarks results in the classification of arsenic and ammonia as Possible Hazards to public health. Concentration of certain contaminants in the drift may aggravate health hazards if the public is exposed to the drift.

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. The potential ecosystem effects have not been assessed quantitatively, due to lack of data.

6.2.3 Coal Lockhopper Vent Gas (Stream 72)

Stream 72 has a relatively low flow rate (3968 lb/hr), but contains a wide variety of trace elements, organics and toxic gases. Chemical characterization data are limited to classes of compounds, with the exceptions of ammonia, carbonyl sulfide, hydrogen cyanide, hydrogen sulfide and nickel carbonyl, which also are quantified.

Comparison of estimated post-dilution concentrations with ecological and public health benchmarks indicates that none of the components in 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. Hazards to public health posed by the classes of compounds have not been assessed because data regarding concentrations of individual compounds are not available. It should be noted that if the total concentration of each class of compounds are compared with the most strigent EPC for any compound in the class, then total trace elements, phenols, fatty acids and mercaptans would be classified as Possible Hazards.

Technology currently exists for reducing or eliminating emissions of coal lockhopper vent gas. Pressurization of coal lockhoppers with nitrogen gas rather than product gas can be used to reduce pollutant releases. If product gas is to be used (as in most commercial Lurgi facilities) collection and incineration of potential releases is a viable alternative. Incineration would eliminate hazards due to organic emissions, but would not reduce the hazard posed by trace elements. Pressurization with nitrogen gas could reduce the hazard posed by both trace elements and organics.

6.2.4. Reverse Osmosis Concentrated Wastes (Stream 53)

Concentrated waste from the reverse osmosis unit is the largest aqueous waste stream requiring ultimate disposal. It has a flow rate of 573,000 lb/hr or 75 liters/sec. It is unique to the facility; its flow rate and composition being a function of process operations, operating conditions, feed coal and wastewater treatment processes. 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 a significant hazard to human health and ecosystems.

Comparison of estimated ambient pollutant concentrations with ecological and public health benchmarks indicates that eleven classes of compounds (trace elements and ten classes of organics) may pose a Probable to Possible Hazard to humans and/or ecosystems.

Estimated ambient concentrations of all ten trace elements for which concentration have been estimated exceed at least one ecological or public health benchmark. 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 public health.

Ten classes of organic compounds are classified as Probable or Possible Hazards to human health and/or ecosystems. Phenols, polynuclear aromatics and mercaptans are classified as Probable Hazards, because estimated post-dilution concentration of at least one compound in each class exceeded one or more benchmarks by at least an order of magnitude. Although the efficiency of removal of phenols prior to reverse osmosis was high (98+%), estimated post-dilution concentrations of twelve of the phenols exceed drinking water standards by at least an order of magnitude. Eight of the phenolic compounds also exceed (or approach) at least one other benchmark.

The paucity of data regarding polynuclear aromatics must be considered in evaluating results of the screening procedure. Polynuclear aromatics have been placed in the Probable Hazard category, because the estimated post-dilution concentration of naphthalene exceeds two benchmarks by at least an order of magnitude and approaches two other benchmarks. Estimated ambient concentrations of fluoranthene and phenanthrene are within an order of magnitude of their Estimated Permissible Concentration values, despite relatively low initial concentrations in Raw Gas Liquor (0.2 mg/l and 0.1 mg/l, respectively) and estimated 90% removal of both compounds prior to entry of the stream into the reverse osmosis unit.

Mercaptans are classified as a Probable Hazard because the estimated post-dilution concentration for the only mercaptan quantified in the stream, methanethiol, exceeds its Estimated Permissible Concentration for Health, (the only available health benchmark), by more than an order of magnitude. It also exceeds the only available ecological benchmark, the Lowest Observed Toxic Concentration, by a factor of three.

Based on the results of the screening process, two classes of organic compounds (carboxylic acids, and substituted benzenes) are classified as Possible Hazards. Three carboxylic acids exceed or approach their Estimated Permissible Concentration, despite removal of over 95% of the compounds prior to treatment in the reverse osmosis unit. All five of the substituted benzenes quantified in the assessment exceed Estimated Permissible Concentrations for health or ecosystems, despite removal of over 90% of the compounds prior to treatment in the reverse osmosis unit.

Five additional classes of organic compounds (aromatic amines; nitrosamines; and nitrogen, sulfur and oxygen heterocyclics) are classified as Possible Hazards, due to uncertainties regarding pollutant concentrations, and toxicologic benchmarks.

Despite extensive treatment of the wastewater, concentrated waste from the reverse osmosis unit poses a Probable Hazard to human health and ecosystems. The stream hazard may be reduced by employing additional (or alternative) treatment technologies or improved disposal methods.

A wide variety of alternative technologies have been proposed for treating/disposing of coal conversion wastewaters. The following brief discussion is provided to indicate some of the advantages, disadvantages and uncertainties associated with several of the proposed alternative treatment and disposal options, including:

- Alternative Treatment
  - Elimination of reverse osmosis unit

- Additional Treatment Options
  - Precipitation
  - Enhanced solvent extraction
  - Activated carbon adsorption
  - Ozonation
  - Enhanced biotreatment

- Alternative Disposal Methods
  - Deep well disposal
  - Forced evaporation and incineration

Elimination of the reverse osmosis unit in the wastewater treatment train and routing of ash sluice water into the biological treatment unit would offer two major advantages: elimination of the concentrated waste stream (Stream 53) and possibly enhancement of biotreatment through dilution of potentially toxic constituents in the biological treatment unit. The major disadvantage resulting from such an alteration would be increased pollutant concentrations in effluent from the wastewater treatment facility. Because the treated effluent is used as cooling tower make-up water, increased pollutant concentrations would increase the environmental hazard associated with cooling tower losses to the atmosphere, Stream 29. When the reverse osmosis unit is employed, only two components of Stream 29 (As and NH_3) pose a hazard (Possible) to public health. If the reverse osmosis unit is deleted, five components of Stream 29 pose a hazard to public health: arsenic poses a Probable Hazard; and ammonia, boron, cadmium and mercury pose Possible Hazards.

Precipitation may be an effective means of reducing concentrations of heavy metals. Use of $Fe(OH)_3$ or another such scavenging agent can be an effective method for removing arsenic, cadmium, lead, mercury and other heavy metals, and can be a relatively inexpensive step when combined with a pre-existing need for settling and/or prefiltration.[212] However effectiveness has not been demonstrated for coal conversion wastewaters. Disadvantages are that it does not reduce the concentration of organics, and it does produce a sludge requiring disposal.

Solvent extraction of organics may be enhanced by substituting methyl isobutyl ketone (MIBK) for diisopropyl ether (DIPE). MIBK has been shown to be substantially better than DIPE for extraction of polyhydric phenols. Appropriately chosen solvents may also prove effective in removing polycyclic aromatic hydorcarbons, heterocyclics, organic bases, organic sulfur compounds, and carboxylic acids as well as phenolics.[212] Although enhanced solvent extraction appears promising, effectiveness has not been demonstrated on actual coal conversion wastewaters, and a residual solvent concentration will inevitably remain in the water. Also, a significant fraction of dissolved organics may prove resistant to solvent extraction. Recent analytical results,[41] obtained from the aqueous process condensates from an oxygen-blown, lignite-fired Lurgi gasifier, indicate that although DIPE extraction reduced phenols by 99% and Total Organic Carbon (TOC) by 75%, subsequent exhaustive extraction (using methylene chloride and diethyl ether) removed only 9% of the remaining TOC. The final TOC remained high, i.e., approximately 1,900 mg/1.

Activated carbon adsorption has been proposed as a polishing step following biotreatment. Carbon adsorption can reduce the concentration of phenolics, color and complexed metal ions. In combination with the prefiltration that is required, the method also eliminates suspended solids. However, carbon adsorption has no effect on inorganic salts, does not affect significantly the reduction of large-molecular-weight materials, and the carbon itself may give rise to pollutants that are leachated into water immediately after regeneration.[212] Also, the final TOC level attainable using activated carbon adsorption may be relatively high. A recent study[41] using Lurgi gasifier condensate (after extraction with DIPE, methylene chloride and diethyl either) indicated that addition of 0.005 mg/1 carbon reduced TOC from 1894 mg/1 to 280 mg/1. However increasing the concentration of carbon up to 0.1 g/ml of water did not reduce the TOC below 171 mg/1. The study concluded that gasification wastewater may not be sufficiently polished by activated carbon due to the high residual TOC level.

Ozonation has been proposed for reducing polynuclear aromatic hydrocarbons, nitrogen heterocyclics, color and toxicity. It has also been proposed for assisting the removal of large-molecular-weight organics by carbon adsorption.[212] Although ozonation appears promising, economic feasibility is unknown and the extent of its capabilities is not well established. Preliminary results of a study[48] evaluating treatment of coal conversion (i.e., hydrocarbonization) wastewater by biological oxidation, activated carbon and ozonation, indicate that the acute toxicity of wastewater to Daphnia magna was reduced significantly by biotreatment, but subsequent treatment with carbon adsorption and ozonation resulted in a significant increase in toxicity. Acute toxicity of the wastewater after adsorption and ozonation was actually higher than for the raw scrubber water. The reason for these unexpected results has not been determined yet, although its is suspected that the increased toxicity may be due to conversion of trace residual cyanates to cyanide on ozonation.

Biological treatment may be enhanced by developing biological sludges specifically for treatment of facility wastewaters. Successful operation has been reliably experienced for seemingly similar wastewaters, such as coke plant effluent. However, to date, results have been considerably less encouraging for coal conversion wastewaters.[212]

Deep well disposal can be an effective method for disposing of the reverse osmosis concentrated waste, but may be limited by site specific conditions. Limited availability of appropriate geological formations and local regulations may prevent use of this option at a given site.

Forced evaporation of the waste stream and incineration of the brine can be used to destroy the organics in Stream 53, but may produce an ash with high concentrations of trace elements and, possibly, some air pollution. The economic feasibility of treating such a large stream has not been determined.

In general, although many treatment processes appear promising, economic feasibility and effectiveness have not been demonstrated on actual coal conversion wastewaters as yet. Final judgment as to the hazard potential of the reverse osmosis concentrated waste must await thorough investigation of the chemical characteristics, acute and chronic toxicity, and treatability of whole effluents from appropriate operating facilities.

6.2.5 Leachate From Ash and FGD Sludge (Stream 69)

Leachate from ash and sludge disposal is not a planned environmental release, but may occur if disposal is in the mine, as in the hypothetical plant. Chemical and physical characteristics of utility ash and scrubber sludge from the hypothetical plant should not differ from ash and scrubber sludge produced by a coal-fired power plant burning Wyoming subbituminous coal. The leachates should also be equivalent. Chemical and physical characteristics of gasifier ash may differ, perhaps significantly, from those of utility ash due to differences in operating conditions. Leachates from the gasifier ash, therefore, may differ as well.

Because 84% of the ash/sludge stream is generated by the gasifier, the quality of the ash is assumed to be similar to gasifier ash. No data are available from leachate from ash from Wyoming Subbituminous coal. The composition of first column volume leachate fractions of unquenched ash from Montana Rosebud coal is assumed to be representative for the assessment. The data are limited to concentrations of trace elements. In the hypothetical Lurgi/Fischer-Tropsch plant ash is quenched and then dewatered prior to disposal. Use of leachate data from unquenched ash, therefore, may result in overestimation of concentrations of trace elements in leachate from the model facility. The assumption that natural attenuation processes (e.g., precipitation, adsorption, ion exchange) are negligible also tends to result in overestimation of trace element concentrations in leachate from the model facility.

Although estimated concentrations of the trace elements appear to be higher than would be expected under actual conditions, results of the screening process (presented in Table 6-1) indicate that none of the trace elements pose a Probable Hazard to either public health or ecosystems. Only one element, nickel, exceeds even a single benchmark. Six elements (Al, Cd, Fe, Pb, Mn, and Se) are classified as Possible Hazards, but only one of the six, selenium, approaches more than one benchmark.

It does not appear that ash leachate poses a significant concern to public health or ecosystems. Final judgement regarding the hazard posed by ash/sludge leachate requires thorough chemical and toxicological characterization of whole ash leachate from operating plants. Of particular importance is the impact that natural weathering processes will have on the long-term leachability of potentially toxic constituents of the ash and sludge. The probability of formation and release of leachate must also be determined.

6.2.6 Biosludge Leachate (Stream 71)

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. For the hypothetical plant toxic materials in biosludge have been estimated by assuming that removal of trace elements and polynuclear aromatic hydrocarbons in the biological treatment is via adsorption and sedimentation with the biosludge. The biosludge is assumed to be disposed of in the mine. Trace elements and polycyclic aromatic hydrocarbons removed with the biosludge are assumed to be leached from the biosludge and enter a small (10 cfs) stream. These assumptions are, of course, very tenuous.

Comparison of estimated ambient concentrations with ecological benchmarks indicates that both classes of compounds for which concentrations have been estimated, (trace elements and polynuclear aromatics,) may pose a Probable Hazard to ecosystems. The estimated post-dilution concentration of all five trace elements for which concentrations have been estimated (As, Be, Cd, Pb, and Hg) exceed from two to seven benchmarks by at least an order of magnitude. Comparison of estimated concentrations of polynuclear aromatics (PNAs) with ecological benchmarks indicates that three of the seven PNA compounds quantified in the assessment exceed at least one benchmark. Naphthalene exceeds or approaches all the available benchmarks. It exceeds its Lowest Observed Toxic Concentration (LOTC) and Proposed Freshwater Criteria (PFC) by more than an order of magnitude, and approaches its Lowest Observed Lethal Concentration (LOLC). Fluoranthene exceeds its LOTC and approaches its PFC. Phenanthrene exceeds its Lowest Observed Toxic Concentration but is considerably lower than its Lowest Observed Lethal Concentration.

Although biosludge is a relatively small stream (i.e., approximately 3,900 lb/hr), and natural attenuation mechanisms (e.g., chemical precipitation, ion exchange, biodegradation) may be expected to reduce pollutant levels, projected high concentrations of trace elements and polynuclear aromatic hydrocarbons indicate that disposal of biosludge with ash in the mine, as assumed in the hypothetical plant, may pose a Probable Hazard to the surrounding ecosystem.

The high concentrations of toxic materials, coupled with the probability that coal conversion biosludge will be declared hazardous under the Resource Conservation and Recovery Act[212] indicate that improved disposal techniques or process modifications will be required. Disposal options include but are not limited to:

- incineration in the utility boiler - this option would destroy organics, utilize the heating value of the biosludge and route most of the trace elements into bottom ash or fly ash. A potential disadvantage would be the substantial increases in trace element flow rates into the boiler and also out of the boiler as atmospheric emissions. Based on estimated flow rates for trace elements (see Section 6.4.1), arsenic would increase by 140%, beryllium by 68%, cadmium by 65%, mercury by 70% and lead by 5%.

- incineration in a specially designed incinerator - this option would destroy organics and allow better control of trace element atmospheric releases. It could produce an ash which would probably require disposal as a hazardous waste due to high concentrations of trace elements. However, the small flow rate of the ash would facilitate treatment (e.g., chemical fixation) and disposal.

- disposal in a secure landfill - disposal in a secure landfill may reduce or eliminate the potential hazard.
- fixation - chemical fixation is a potential method for reducing the leachability of biosludge, but its applicability to biosludge from indirect liquefaction processes has not been demonstrated. Long-term leaching potentials are not fully understood at this time.
- elimination of biological treatment unit - substitution of other wastewater treatment processes (e.g., physical and chemical processes) for biological treatment would, of course, eliminate production of biosludge. Environmental tradeoffs would depend upon the specific alternatives selected.

6.2.7 Process Streams (Streams 7-18, 51, 55, 56, 66 and 68)

Only streams where carbon monoxide is present have been addressed. These include: raw to purified gas streams, Fischer-Tropsch products, SNG, biotreatment waste air, Rectisol sour gas, Stretford incineration gas, Fischer-Tropsch product upgrading heater stack gas, and Fischer-Tropsch product CO_2 off-gas. These streams have been analyzed only in the occupational health assessment. They do not represent public health or ecological concerns. The most important occupational concerns are associated with tars and oils from the purification of the raw gas (Streams 7-12), methane from SNG (Stream 18), hydrogen sulfide from product upgrading heater stack gas (Stream 66), and fatty acids from washed gas (Stream 8).

6.3 CATEGORIZATION OF CHEMICAL CLASSES BY HAZARD LEVEL

In this section the hazards associated with various chemical groups are evaluated after considering their occurence, effects and degree of hazard in all analyzed process and waste streams. Table 6-3 contains a summary of the analyses of constituents associated with aqueous environmental releases and atmospheric environmental releases, respectively.

6.3.1 Trace Elements

Information in Tables 6-1, 6-2 and 6-3 indicates that trace elements may represent one of the greatest hazards posed by the

TABLE 6-3

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

	GASEOUS STREAMS								LIQUID AND SOLID STREAMS							
	ESTIMATED HAZARD LEVEL IN QUANTIFIED STREAMS*							PRESENCE IN UNQUANTIFIED STREAMS*	ESTIMATED HAZARD LEVEL IN QUANTIFIED STREAMS*							PRESENCE IN UNQUANTIFIED STREAMS*
CLASSES OF COMPOUNDS	ECOLOGICAL			PUBLIC HEALTH			OCCUPATIONAL HEALTH		ECOLOGICAL			PUBLIC HEALTH			OCCUPATIONAL HEALTH	
	28	29	72	28	29	72			53	69	71	53	69	71		
TRACE ELEMENTS	◉	P	○	◉	◉	P	○	H-7,24-26 M-11,16 L-1,2,8-10,12-15	●	◉	●	●	◉	●	-	H-3,27,33,79 M-17,37-40,43,46 L-32,34,44,54
ALIPHATICS, ALICYCLICS AND FATTY ACIDS	-	P	○	-	○	P	◉	H-7,73,74 M-11,55 L-8,9,10,12	◉	-	-	◉	-	-	-	H-52 M-17,39-43,46,48,57-59 L-50,59
SUBSTITUTED BENZENES	-	P	-	-	○	-	-	H-7,75	◉	-	-	◉	-	-	-	
PHENOLS	-	P	◉	-	○	-	○	H-7,75,76,77 M-11 L-8-10,12	◉	-	-	◉	-	-	-	H- M-17,39-43,46-48,58,59 L-
PNA	-	P	○	-	○	-	○	H-7,75,76 M-11,55 L-8-10,12-15	●	-	●	◉	-	●	-	H-27,52,70 M-17,22,23,39-43,46-48, 57-59
SULFUR HETEROCYCLICS	-	P	○	-	P	-	○	H-7,75 M-11,16,55 L-8-10,12-15	-	-	-	-	-	-	-	M-39-43,46-48,57 L-44,45,50
NITROGEN HETEROCYCLICS	-	P	-	-	○	-	○	H-7	○	-	-	○	-	-	-	H-52 M-39-43,46-48
OXYGEN HETEROCYCLICS	-	-	-	-	-	-	○	H-7,76	-	-	-	-	-	-	-	H-52 M-39-43,46-48
MERCAPTANS	-	P	○	-	○	-	○	H-7 M-11,16,55 L-8-10,12-15	◉	-	-	●	-	-	-	H-52 M-39-43,46-48,57-59 L-44,45,50
AROMATIC AMINES	-	P	○	-	○	-	○	H-7 M-11,55 L-8-10,12-15	○	-	-	○	-	-	-	H-27,52 M-39-43,46-48,57-59 L-44,45,50,54
NITROSAMINES	-	P	○	-	P	-	○	H-7 M-11,55 L-8-10,12-15	-	-	-	-	-	-	-	H-27,52 M-39-43,46-48,57-59 L-44,45,50,54
AMMONIA	-	P	○	-	◉	◉	○	H-7 M-11,16,55 L-8-10,12-15,56	P	-	-	-	-	-	-	H-52 M-39-43,46,48,49,57-59 L-50
CARBONYL SULFIDE	-	-	○	-	-	○	-	H-7 M-11,55 L-8-10,12-15,56	-	-	-	-	-	-	-	H-63

TABLE 6-3 (concluded)

CLASSES OF COMPOUNDS	GASEOUS STREAMS								LIQUID AND SOLID STREAMS							
	ESTIMATED HAZARD LEVEL IN QUANTIFIED STREAMS*							PRESENCE IN UNQUANTIFIED STREAMS*	ESTIMATED HAZARD LEVEL IN QUANTIFIED STREAMS*							PRESENCE IN UNQUANTIFIED STREAMS*
	ECOLOGICAL			PUBLIC HEALTH			OCCUPATIONAL HEALTH		ECOLOGICAL			PUBLIC HEALTH			OCCUPATIONAL HEALTH	
	28	29	72	28	29	72			53	69	71	53	69	71		
HYDROGEN CYANIDE	-	-	○	-	-	○	○	H-7 M-11,55 L-8-10,12-15	-	-	-	-	-	-	-	M-39-43,46-48,57 L-44,45
HYDROGEN SULFIDE	-	-	○	-	-	⊙	○	H-7,51 M-11,55 L-8-10,12-15,56,64,66	-	-	-	-	-	-	-	H-63 M-43,46,48 L-44,45,50
NICKEL CARBONYL	-	-	○	-	-	⊙	○	H-7 M-11,16,18,55 L-8-10,12-15,56	-	-	-	-	-	-	-	H-63 M-41-43 L-44,45
NITROGEN OXIDES	⊙	-	-	⊙	-	-			-	-	-	-	-	-	-	
SULFUR OXIDES	⊙	-	-	⊙	-	-	○		-	-	-	-	-	-	-	
TARS	-	-	-	-	-	-	●	H-7,76 M-11 L-8-10,12	-	-	-	-	-	-	-	M-39-43,46 L-44
OILS	-	-	-	-	-	-	●	H-7 M-11 L-8-10,12	-	-	-	-	-	-	-	H-17,52 M-39-43,46-48,57-59 L-44,45,50,54

KEY:

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

● - Probable Hazard

⊙ - Possible Hazard

○ - Unlikely Hazard

P - Class present, hazard level not established

- - Class presence unknown, hazard level not estimated hypothetical indirect liquefaction facility. Estimated trace element concentrations in all of the quantified streams (except lockhopper vent gas, for which data are very limited) pose a Possible to Probable Hazard to public health and ecosystems. Concentrations in internal process streams (e.g., Stream 13) are estimated to be high enough to approach, though not exceed, Threshold Limit Values in the occupational environment. And trace elements are present in a large number of unquantified gaseous, liquid and solid streams which have a high to medium probability of release to the environment.

Several of the elements have been identified as presenting a greater hazard than others. Arsenic, beryllium, cadmium, lead, manganese, mercury and nickel pose the greatest relative hazards to ecosystems. Beryllium and nickel pose the greatest relative hazards to human health, while arsenic, boron, cadmium, lead, mercury, and vanadium pose Possible Hazards to public health. The ecological assessment of threshold bioaccumulation concentrations for arsenic, cadmium, lead, manganese and mercury also suggests that these metals may accumulate in fish tissue to levels that present human health hazards from dietary intake.

The high degree of hazard posed by trace elements relative to the other chemical groups assessed may be biased by the substantially greater amount of toxicologic information available and hence the likelihood that more sensitive species have been tested with trace elements. However the large number of toxicologic benchmarks exceeded by projected post dilution concentrations of trace elements in quantified waste streams indicates the importance of isolating these waste streams from the environment.

The environmental hazards are aggravated by the large quantities of trace elements processed and the number of streams which may contain them. Because the hypothetical facility processes a large quantity of coal (28,000 TPSD), the total environmental loading of trace elements will be high. For example if a trace element is present in the Wyoming subbituminous coal at a level of 1 ppm (dry basis), approximately 40 pounds per stream day of that trace element will enter and leave the plant. Total quantities of trace elements processed by the hypothetical facility are presented in Table 6-4. As shown in the Table, up to 16,126 pounds of arsenic, 10,751 pounds of beryllium and cadmium, 215,024 pounds of chromium, 2,284 pounds of mercury, 161,268 pounds of lead, and 11,826 pounds of uranium will be processed by the hypothetical plant in a single year. The distribution of selected elements (As, Be, Cd, F, Hg and Pb) in the hypothetical facility has been estimated using SASOL trace element distribution coefficients for Lurgi gasifiers and utility boilers and the uppper value of trace element content of Wyoming subbituminous coal. The distribution is presented in Figure 6-1. Inspection of the trace element distribution in quantified streams indicates that although the largest flow of trace elements is in Stream 36 (ash/scrubber sludge), significant quantities of trace elements are present in several other streams which may be released to the environment, including reverse osmosis permeate and concentrate, ash leachate, biosludge leachate, and atmospheric emissions from the utility boilers.

Because trace element content varies greatly among coals, use of a coal other than the Wyoming subbituminous coal assumed in the assessment, may have a significant impact on trace element input to the hypothetical facility. The concentration of fourteen trace elements in Wyoming subbituminous coal is compared with concentrations in other U.S. coals in Table 6-5. As shown in the table, the maximum concentrations of all but two trace elements (antimony and chromium) in the Wyoming subbituminous coal are less than the mean concentration for 101 other U.S. coals; the maximum concentrations of trace elements in the 101 coals are from 5.6 to 668 times as large as maximum concentrations in Wyoming subbitiminous coal. Maximum concentrations of trace elements in Wyoming subbituminous coal also are approximately equal to, or lower, than concentrations in coals from four major U.S. coal regions. This brief comparison of coals suggests that substitution of many U.S. coals

TABLE 6-4

TOTAL QUANTITY OF TRACE ELEMENTS PROCESSED BY THE HYPOTHETICAL FACILITY

TRACE ELEMENTS	CONCENTRATION IN WYOMING SUBBITUMINOUS COAL[74] (ppm)	TOTAL QUANTITY INTO FACILITY (lb/sd)	TOTAL QUANTITY (lb/year)
Ag	.06-.43	2.40-17.21	806.3-5,778.8
As	.57-1.2	22.81-48.03	7,660.2-16,126.8
B	32	1280.67	430,048.
Ba	87	3481.83	1,169,193.
Be	.71-.8	28.42-32.02	9,541.7-10,751.2
Cd	.31-.8	12.41-32.02	4,166.1-10,751.2
Co	.55	22.01	7,391.5
Cr	4.2-16	168.09-640.34	56,443.8-215,024.
Cu	8.9-10	356.19-400.21	119,607.1-134,390
F	65-67	2601.37-2681.41	873,535-900,413
Hg	.11-.17	4.40-6.80	1,478.3-2,284.6
Li	3.6-15.0	144.08-600.32	48,380.4-201,585.
Mo	2.2	88.05	29,565.8
Mn	2.8-3.4	112.06-136.07	37,629.2-45,692.6
Ni	1.7-14	68.04-560.29	22,846.3-188,146.
Pb	.51-12	20.41-480.25	6,853.9-161,268.
Sb	.08-1.5	3.20-60.03	1,075.1-20,158.5
Se	.33	13.21	4,434.9
Sn	.14	5.60	1,881.5
U	.88	35.22	11,826.3
V	10-14	400.21-560.29	134,390.-188,146.
Zn	.23-8	9.21-320.17	3,091.0-107,512.

FIGURE 6-1

TRACE ELEMENT DISTRIBUTION IN THE HYPOTHETICAL PLANT
(lb/hr)

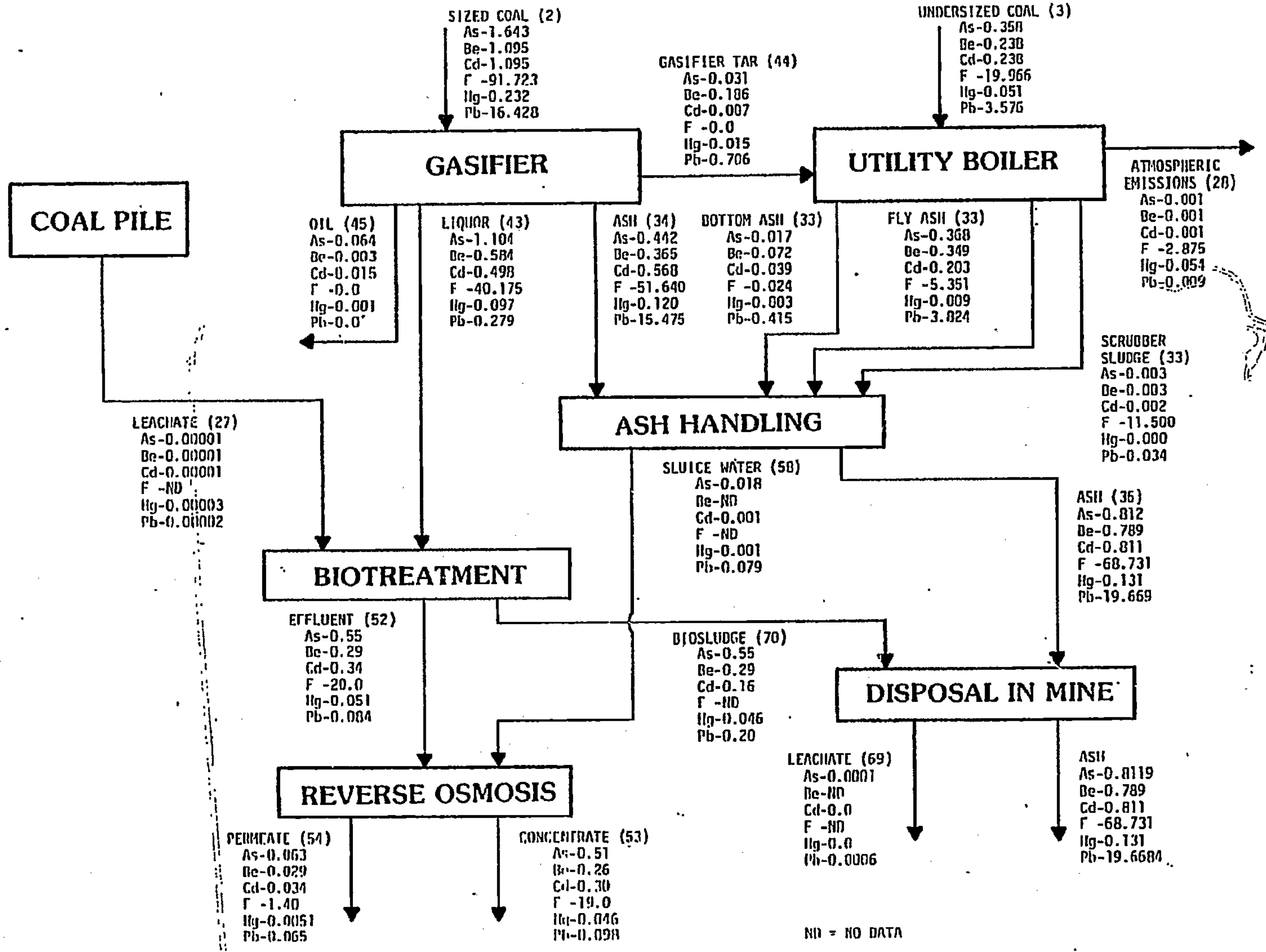


TABLE 6-5

TRACE ELEMENT CONTENT OF U.S. COALS
(ppm)

TRACE ELEMENT	WYOMING[74] SUBBITUMINOUS COAL	MEAN ANALYTICAL VALUES FOR 101 U.S. COALS[10]				TRACE ELEMENT CONTENT OF COALS BY REGION[10]			
		MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM	POWDER RIVER BASIN	WESTERN INTERIOR	EASTERN INTERIOR	APPALACIAN
Antimony	0.08-1.5	1.26	1.32	0.20	8.90	0.67	3.5	1.3	1.2
Arsenic	0.57-1.2	14.02	17.70	0.50	106.00	3.0	16.0	14.0	18.0
Beryllium	0.71-0.8	1.61	0.82	0.20	31.00	0.7	2.0	1.8	2.0
Boron	32	102.21	54.65	5.00	356.00	-	-	-	-
Cadmium	0.31-0.8	2.52	7.60	0.10	65.00	2.1	20.0	2.3	0.2
Chromium	4.2 - 16	13.75	7.26	4.00	610.00	-	-	-	[illegible]
Copper	8.9 - 10	15.16	8.12	5.00	61.00	-	-	-	-
Lead	0.51-12	34.78	43.69	4.00	218.00	7.2	-	34.0	12.0
Manganese	2.8 - 3.4	49.40	40.15	6.00	181.00	-	-	-	-
Mercury	0.11-0.17	0.20	0.20	0.02	1.60	0.1	0.13	0.19	0.16
Nickel	1.7 - 14	21.07	12.35	3.00	104.00	-	-	-	-
Selenium	0.33	2.08	1.10	0.45	8.00	0.73	5.7	2.5	5.1
Vanadium	10 - 14	32.71	12.03	11.00	78.00	-	-	-	-
Zinc	0.23-8	272.29	694.23	6.00	5,350.00	33.0	-	250.0	13.0

for the Wyoming subbituminous coal used in the assessment would tend to increase the environmental hazard posed by trace elements.

6.3.2 Aliphatics, Alicyclics and Fatty Acids

Compounds in these classes are present in a number of quantified and unquantified streams. Concentrations in gaseous streams are estimated to pose an Unlikely Hazard to public health and ecosystems, but a Possible Hazard to occupational workers who may be exposed to leaks from internal process streams (e.g., fatty acids in Washed Gas - Stream 8, and methane in SNG - Stream 18).

Although concentrations from aqueous streams initially were categorized as Possible Hazards to public health and ecosystems, these compounds probably do not represent serious off-site hazards because they are generally widespread in the environment, are not highly toxic and are readily biodegraded.

6.3.3 Benzenes and Substituted Benzenes

Several of these compounds are expected to be present in the gaseous and aqueous streams. As indicated in Table 6-3, these compounds have been classified as Possible Hazards to both aquatic ecosystems and public health (via consumption of contaminated drinking water). Atmospheric releases appear to pose an Unlikely Hazard to public health and ecosystems. This chemical class has not been assessed in the occupational health assessment.

6.3.4 Phenols

Phenols are present in a large number of gaseous and aqueous streams that have a high to medium probability of release. Estimated ambient concentrations due to gaseous releases appear to pose an Unlikely Hazard to public and occupational health. The concentration in Coal Lockhopper Vent Gas is categorized as a Possible Hazard to ecosystems, but can probably be controlled by incinerating the vent gas. Post-dilution concentrations of phenols due to release of reverse osmosis concentrated waste (Stream 53) are classified as a Possible

Hazard to ecosystems and public health. Although comparison of post-dilution concentrations with Drinking Water Standards indicate that a Probable Hazard level may exist for human health, the standards are based on the organoleptic characteristics of phenols, which are generally several orders of magnitude greater than toxic concentrations. Similarly, although estimated ambient concentrations of catechol and resorcinol exceed thier respective EPCs for ecology by at least an order of magnitude, comparison of estimated concentrations with toxicologic benchmarks (Lowest Observed Lethal Concentrations and Lowest Observed Toxic Concentrations) indicates a Possible Hazard level is a more appropriate classification.

6.3.5 Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic hydrocarbons are present in a large number of gaseous, aqueous and solid streams that have a high to medium probability of release. Estimated ambient concentrations due to gaseous emissions do not appear to pose a very significant hazard to public health, ecosystems and occupational health, however this could be the result of the paucity of data regarding the presence and concentration of PNA in gaseous streams and incompleteness of data regarding biological activity at low levels of exposure.

Concentrations of PNA in aqueous and solid streams are classified as Possible to Probable Hazards to public health and ecosystems. Estimated ambient concentrations due to release of reverse osmosis concentrate (Stream 53) are categorized as a Possible Hazard to public health and a Probable Hazard to ecosystems. Estimated ambient concentrations due to release of PNA in biosludge pose a Probable Hazard to both public health and ecosystems. Occupational hazards posed by PNA in liquid and solid streams have not been assessed. The presence of PNA in streams that have not been characterized in detail will increase the environmental loading and may increase the environmental hazards posed by the PNA.

Naphthalene and, to a lesser extent, fluoranthene and phenanthrene appear to pose the most significant hazards. However toxicological information is insufficient to assess adequately the potential environmental hazards posed by many of the PNAs.

Due to the substantial uncertainties in the data base, the anticipated presence of PNA in unquantified facility streams and the adverse toxicologic properties (carcinogenic, mutagenic, biorefractory, bioaccumlative) associated with some members of this class of compounds, PNA tentatively should be classified as Probable Hazards to ecosystems, and public and occupational health.

6.3.6 Sulfur, Nitrogen and Oxygen Heterocyclics

Information regarding sulfur, nitrogen and oxygen heterocyclics is very limited. Data regarding concentrations, treatability, and toxicity of heterocyclic compounds are so limited that no conclusions regarding the magnitude of the potential hazard that they pose to the environment may be made based upon the assessment. However, several observations may be made:

- heterocyclics have been detected in a number of streams in Lurgi facilities, including tar, oil, raw gas, and raw gas liquor and may be expected to occur in indirect liquefaction facilities utilizing Lurgi gasifiers.

- the treatability of heterocyclics is not well understood. Although individual nitrogen-containing monoaromatic bases have been easily degraded in bench-scale biological treatment units, pyridine, quinoline, and the alkylated derivatives in coking and petrochemical effluents often pass essentially unchanged though treatment plants.[154] Solvent extraction of aromatic bases has been reported to exceed 99% in some studies,[18] but considerably lower effective in other studies[212], possibly due to pH effects.

- the toxicity of heterocyclics is very poorly understood. The presence of nitrogen or sulfur heteroatoms in polyaromatic hydrocarbon structures have been noted to either intensify or lessen carcinogenicity.[173] Unlike many chemical classes of compounds, toxicity data from one fused heterocyclic compound cannot be extrapolated to predict hazards associated with structurally similar compounds. Minor changes in structure may have significant effects on the toxic properties of these compounds.[35]

Due to the expected presence of these compounds in facility streams, the adverse toxicologic properties of several members of their classes, and the high degree of uncertainty regarding their treatability and toxicity, heterocyclic compounds are categorized as Possible Hazards to human health and ecosystems, and should be the subject of further research and assessment.

6.3.7 Mercaptans

Mercaptans are projected to be present in several gaseous and liquid streams in the hypothetical facility. Mercaptans in gaseous streams appear to pose an Unlikely Hazard to public and occupational health, and ecosystems however characterization data for the streams are very limited. The estimated ambient concentration due of mercaptans to reverse osmosis waste (Stream 53) is categorized as a Probable Hazard to public health (based on comparison with the relevant Estimated Permissible Concentration), and a Possible Hazard to ecosystems (based on comparison with its Lowest Observed Toxic Concentration).

6.3.8 Aromatic Amines

Aromatic amines are projected to be present in the cooling tower atmospheric losses (Stream 29), coal lockhopper vent gas (Stream 72) reverse osmosis concentrate (Stream 53), and an additional fourteen streams with a high to medium probability of release to the environment. Results of the screening procedure indicate that the projected ambient concentration of aniline (the one aromatic amine for which the concentration in raw gas liquor was estimated) would pose an Unlikely Hazard to occupational and public health, and ecosystems. However, because aromatic amines are projected to be present in a large number of streams for which quantitative data are not available, and because they have been identified as the compound class of primary concern regarding mutagenic activity in various coal conversion products and wastes, [48,61] aromatic amines are categorized as Possible Hazards to human health and ecosystems.

6-3.9 Nitrosamines

Nitrosamines are expected to be present in a variety of gaseous and liquid streams, a number of which have a medium to high probability of release to the environment. No data regarding specific compounds and concentrations are available for the assessment. Although results of the screening procedures do not indicate that nitrosamines pose a hazard to any of the three receptor groups, they are classified as Possible Hazards because there is a paucity of data regarding specific compounds and concentrations, and because numerous nitrosamines have demonstrated carcinogenic potential[34].

6.3.10 Ammonia

Ammonia is expected to be present in gaseous and liquid streams. Adequate removal of ammonia appears feasible; although, very complete removal of ammonia may entail increased expense (e.g., for taller stripping columns or increased steam consumption) or encounter some problems (e.g., volatility of ammonia may be reduced by chemical interaction with phenols, carboxylic acids, chloride or others non-volatile anions, and break-point chlorination of process waters may produce potentially hazardous chlorinated organics).[212]

Based on results of the screening process the estimated maximum ground level concentration of ammonia resulting from release of coal lockhopper vent gas (Stream 72) poses a Possible Hazard to public health and an Unlikely Hazard to ecosystems. The estimated maximum ground level concentration due to cooling tower evaporative losses (Stream 29) poses a Possible Hazard to public health. However, because ammonia is a common environmental compound, is rapidly oxidized in the environment, and control technologies exist for reducing ammonia to low levels in cooling tower make-up water and coal lockhopper vent gas, ammonia is categorized as an Unlikely Hazard to all receptor groups.

6.3.11 Carbonyl Sulfide

Data regarding carbonyl sulfide are limited. It is expected to be present in coal lockhopper vent gas and internal process streams. It appears to pose an Unlikely Hazard to public health and ecosystems. The hazard to the occupational population has not been assessed.

6.3.12 Hydrogen Cyanide

Hydrogen cyanide is expected to be present in coal lockhopper vent gas and internal process streams. Results of the assessment indicate that it appears to pose an Unlikely Hazard to public and occupational populations and ecosystems.

6.3.13 Hydrogen Sulfide

Hydrogen sulfide is expected to be present in coal lockhopper vent gas and a large number of internal process streams. The estimated ground level concentration due to release of the lockhopper vent gas is categorized as a Possible Hazard to public health and ecosystems. The hazard level due to the total environmental loading for all streams is not known. Incineration of the lockhopper vent gas may reduce the hazard level for that particular stream, but H_2S concentrations due to leaks in internal process streams may still pose a significant hazard.

Based on the results of the indicator compound/monitoring assessment, hydrogen sulfide is projected to pose a Possible Hazard to occupational workers. Modification of the indicator compound/monitoring system (e.g., using a different indicator compound or reducing the allowable level of indicator compound in workplace air) may reduce the hazard posed by H_2S.

6.3.14 Nickel Carbonyl

Nickel carbonyl is projected to be present in coal lockhopper vent gas and leaks from several internal process streams.

The occupational health assessment indicates that if the concentration of $Ni(CO)_4$ is workroom air is controlled via the CO indicator compound/monitoring method, it will pose a Possible Hazard to occupational personnel.

Estimated maximum ground level concentration of $Ni(CO)_4$ due to release of coal lockhopper vent gas is projected to pose a Potential Hazard to public health and ecosystems. The hazard level associated with the total environmental loading of $Ni(CO)_4$ from the facility as a whole, has not been assessed. Incineration of the lockhopper vent gas will reduce the environmental loading, but the resultant hazard level has not been determined due to insufficent data. Overall, $Ni(CO)_4$ is classified as a Possible Hazard to all potential receptor groups.

6.3.15 Carbon Dioxide

Carbon dioxide emissions have not been addressed in the ecological or public health assessments. From a public health and environmental perspective they are of concern only as a minor contributor to the potential global problem of climate alteration. Carbon dioxide will have no direct, acute, adverse ecological or public health effects. It does represent a potential occupational health problem from stack-gases from the Fischer-Tropsch product up-grading heaters (Stream No. 66). However, by controlling the concentration of the indicator compound (carbon monoxide) in the occupational setting to an appropriate level (a fraction of its TLV) carbon dioxide hazards can be controlled adequately. Thus, carbon dioxide appears to pose an Unlikely Hazard to all receptor groups.

6.3.16 Tars and Oils

Tars and oils are expected to be present in coal lockhopper vent gas and internal process streams. They have not been assessed in the public health or ecological assessment, because no toxicological benchmarks exist that can be used to evaluate such a broad spectrum of chemicals. The maximum ground level concentrations of tars and oils released in the lockhopper vent gas may exceed National Ambient Air Quality Standards for non-methane hydrocarbons; the hazard posed by total environmental loading from the facility as a whole has not been assessed. Incineration of the vent gas will reduce the projected ambient concentrations - but the resultant hazard level cannot be estimated due to lack of characterization data. As a group, tars and oils from process stream leaks and spills are classified as a Probable Hazard to workers. Exposures may occur from inhalation and dermal contact. Carcinogenic and co-carcinogenic constituents are suspected present in tars and oils. They are the most serious occupational health hazard addressed in this study. Worker exposures to the materials probably cannot be totally avoided, but can be reduced through adherence to a comprehensive industrial hygiene program.

6.3.17 Nitrogen Oxides and Sulfur Oxides

Approximately 960 lbs/hour of SO_x (as SO_2) and 176 lbs/hour of NO_x will be released to the environment in the utility stack gas from the hypothetical facility.

Although SO_x emissions will be reduced by lime scrubbing to approximately one-sixth of the New Source Performance Standards for fossil fuel fired steam generators using subbituminous coal, the estimated ambient concentration of SO_x (700 $\mu g/m^3$) will exceed the National Ambient Air Quality Standard (Annual) of 80 $\mu g/m^3$. However this ambient concentration has been estimated using a dilution factor from the EPA Source Analysis Model (SAM/I), which projects maximum ground level concentrations, whereas the annual NAAQS is set for annual average concentrations. Comparison of the projected ambient concentration with the more appropriate 24 hour standard (365 $\mu g/m^3$) and 3 hour standard (1300 $\mu g/m^3$) indicates that the hazard to public health and ecosystems will be considerably lower.

The maximum ground level concentration of NO_x, estimated using a dilution factor from the SAM/I model, is projected to be 130 $\mu g/m^3$. The annual NAAQS for NO_x is 100 $\mu g/m^3$. No national standard with a shorter averaging time has been set; however some states, such as North Dakota, have set standards at 200 $\mu g/m^3$ for a 1-hour average. Comparison of the projected maximum ground level concentration with the more appropriate 1-hour state standards indicates that NO_x would approach, but not exceed the standard.

The primary utility of comparing estimated maximum ground level concentrations of NO_x and SO_x with standards is to demonstrate the uncertainty associated with the assessment and to re-emphasize the need for caution in evaluating and using the results.

6.3.18 Final Analysis of Hazard Categories for Chemical Classes

As described in the previous subsections, the information presented in Table 6-3 has been modified slightly to account for the degree of uncertainty associated with certain estimates of total environmental loadings, toxicologic benchmarks, control technology 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 6-6 lists the final hazard categories fo the classes of compounds addressed in this assessment.

6.4 SUMMARY OF CONCLUSIONS

Process and waste streams of commercial-scale, Lurgi/Fischer-Tropsch liquefaction facilities may be expected to contain a variety of chemical substances known or suspected to be hazardous to human health or the environment. Although it does not appear that any of the hazards are inherently insurmountable (because a variety of alternative control and disposal options are available), site-specific and economic constraints may limit the level to which wastes will be treated, secured, recycled, or reduced in volume.

In the present study, 79 process and waste streams from a model, commercial-scale facility have been identified for initial chemical characterization. Of these, nine gaseous emission streams, ten aqueous and solid waste streams, and numerous process streams have been characterized in more detail. Based upon the assumptions and limitations of the present study, a considerable number of trace contaminants have been determined to be of potential concern, even after being subjected to a substantial degree of treatment. The degree of hazard associated with these contaminants varies considerably among

TABLE 6-6

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, and fatty acids	Ammonia*
Polynuclear Aromatic Hydrocarbons	Benzenes and Substituted Benzenes	Carbonyl Sulfide
Mercaptans	Phenols	Hydrogen Cyanide
Tars and Oils	Sulfur, Nitrogen and Oxygen Heterocyclics*	Carbon Dioxide
	Aromatic Amines*	
	Nitrosamines*	
	Hydrogen Sulfide	
	Nickel Carbonyl	
	Sulfur and Nitrogen Oxides	

*These chemical classes have had their hazard level either upgraded or downgraded from that identified in Table 6-3 based upon consideration of these additional factors: the degree of uncertainty associated with estimates of environmental loading, toxicologic benchmarks, control technology options, and biodegradation.

streams and receptor groups. Trace metals, polycyclic aromatic hydrocarbons, mercaptans, and tars and oils have been classified as Probable Hazards to one or more receptor groups (i.e., occupational personnel, general public, and/or ecosystems).

In addition to these constituents, aliphatics, alicyclics and fatty acids, benzenes and substituted benzenes, phenols, sulfur, nitrogen and oxygen heterocyclics, aromatic amines, nitrosamines, hydrogen sulfide, nickel carbonyl, nitrogen oxides and sulfur oxides are classified as Possible Hazards.

Probable Hazards have been identified in the reverse osmosis waste stream, leachate from biosludge, and internal gasifier streams. Possible Hazards are 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.

The present study represents a comprehensive summary of the available information concerning the identification 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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TABLE A-1

ESTIMATED PROCESS STREAM CONCENTRATION FOR THE RISK ASSESSMENT OF
INDIRECT (LURGI/FISCHER-TROPSCH) COAL LIQUEFACTION PROCESS

Component		Stream Number											
		1	2	3	4	5	6	7	8	9	10	11	12
FLOWRATE, lb mol/h													
CO	28.01							21459	21459	21459	21459	4042	17416
CO_2	44.01							33724	33724	33724	33722	6353	27370
H_2	2.02							44332	44332	44332	44332	8359	35973
CH_4	16.04							12866	12866	12866	12866	2424	10442
C_2H_4	28.05							86	86	86	86	16	69
C_2H_6	30.07							614	614	614	614	116	498
N_2 + inerts	28.01				278	55554		310	310	310	310	59	252
O_2	32.00				14060	781							
H_2S	34.08							158	158	158	157	30	128
COS	60.07							2	2	2	2	<1	2
H_2O	18.02						94379	88481	93936				
Others													
Total gas flowrate, lb mol/h					14338	56335	94379	202032	207487	113551	113548	21400	92150
Temperature, °F		Amb.[b]	Amb.	Amb.	290	Amb.	748	900[c]	700[c]	400[c]	367	367	367
Pressure, psig		Atm.[b]	Atm.	Atm.	480	Atm.	660	450[c]	445[c]	425[c]	414	414	414
FLOWRATE, lb/h													
H_2O		648487	532390	115917		11567				1692727	1425476	268531	1156945
Methanol													
Tar								36311	39504	39504	4438	835	3603
Oil								51911	53255	53255	38467	7246	31221
Naphtha								15675	15675	15675	15675	2953	12722
Crude phenols								15193	16189	16189	5234	986	4248
Mercaptans[d]								40	42	42	20	6	14
Thiophenes[d]								35	36	36	16	5	11
Ammonia								9812	9985	9985	8078	1522	6556
HCN[e]								8	8	8	8	2	6
Aromatic amines[e]								4	4	4	4	1	3
Nitrosamines[e]								2	2	2	2	<1	2
PNA								80	82	82	2	1	1
Fatty acids								2799	2976	2976	1079	194	835
$Ni(CO)_4$[f]								5	6	6	6	2	4
Minerals		116959	96020	20904									
Coal		1549420	1271963	277067									
Sulfur													
Particulates								4106	4516	4516			
Trace elements[g]		1158	951	201				7	8	8	2	1	1
Others													
Total liquid/solid flowrate, lb/h		2316024	1901324	414089		11567		135988	142288	1835015	1498457	282280	1716172
TOTAL STREAM FLOWRATE, lb/h		2316024	1901324	414089	457707	1592627	1700710	4146482	4251081	4251081	3914406	2374104	3177001
Radioactivity[h]		2.6	2.6					0.1	0.1	0.1	0.1	0.1	0.1

Footnotes are given at the end of the table.

TABLE A-1 (CON'T)

Component		Stream Number										
		13	14	15	16	17	18	19	20	21	22	23	24^{k}
FLOWRATE, lb mol/h													
CO	28.01	1218	17416	18634	18500	483	13						
CO_2	44.01	9177	27370	36546	2900	3102	85						
H_2	2.02	11184	35973	47156	46985	9337	719						
CH_4	16.04	2424	10442	12866	12460	14258	17055						
C_2H_4	28.05	16	69	86	21	381	188						
C_2H_6	30.07	116	498	614	277	818	445						
N_2 + inerts	28.01	59	252	310	309	309	308						4
O_2	32.00												1
H_2S	34.08	30	128	157									
COS	60.07	<1	2	2									
H_2O	18.02										2	1	1
Others					1^{i}								
Total gas flowrate, lb mol/h		24225	92150	116371	81453	28688	18813				2	1	6
Temperature, °F		86	86	86	68	100	130	100	100	100	130	130	Amb.
Pressure, psig		400	400	400	348	248	1000	350	146	142	100	100	Atm.
FLOWRATE, lb/h													
H_2O		710	2474	3184		117	36						168
Methanol					200	pp^{j}							
Tar													
Oil						pp							
Naphtha		2953	12722	15675	15675	pp				16056			
Crude phenols						pp							
$Mercaptans^{d}$		2	4	6	<1								
$Thiophenes^{d}$		1	3	4	<1								
Ammonia		15	66	81	17								
HCN^{e}		1	3	4									
Aromatic $amines^{e}$		<1	2	3									
$Nitrosamines^{e}$		<1	1	2									
PNA		pp	pp	pp		pp					pp	pp	
Fatty acids						pp							
$Ni(CO)_4{}^{f}$		<1	<1	2	<1		<1						
Minerals													25
Coal													310
Sulfur													
Particulates													92
Trace $elements^{g}$		1	1	2	1	1							5
Others						185977^{m}	8903^{m}	8190^{m}	1245^{m}	124862^{m}	25390^{m}	7436^{m}	
Total liquid/solid flowrate, lb/h		3686	15277	18963	15696	186095	8940	8190	1245	140918	25390	7436	600
TOTAL STREAM FLOWRATE, lb/h		509687	1976108	2405795	973482	627641	315340	8190	1245	140918	25426	7454	762
$Radioactivity^{h}$		0.1	0.1	0.1	0.05								2.6

TABLE A-1 (CON'T)

Component	25[k]	26[k]	27[l]	28	29	30	31	32	33	34	35	36
	Stream Number											
FLOWRATE, lb mol/h												
CO 28.01												
CO_2 44.01				62254								
H_2 2.02												
CH_4 16.04												
C_2H_4 28.05												
C_2H_6 30.07												
N_2 + inerts 28.01		4		129696								
O_2 32.00		1		2227								
H_2S 34.08												
COS 60.07												
H_2O 18.02		1										
Others				19[n]								
Total gas flowrate, lb mol/h		6		194192								
Temperature, °F	Amb.	Amb.	60	100	Amb.	Amb.	60	70	70	180[c]	Amb.	Amb.
Pressure, psig	Atm.	Atm.	Atm.	Atm.	Atm.	Atm.	5	5	5	10[c]	Atm.	Atm.
FLOWRATE, lb/h												
H_2O	166		1030	497676	2413000	10000	1179700	878977		199486	25500	20000
Methanol												
Tar												
Oil												
Naphtha												
Crude phenols												
Mercaptans[d]												
Thiophenes[d]												
Ammonia												
HCN[e]												
Aromatic amines[e]			PP		PP							
Nitrosamines[e]			PP		PP							
PNA			PP		PP							
Fatty acids												
$Ni(CO)_4$[f]				2								
Minerals	25		2					4420	20950	96031		116989
Coal	310									7038		7038
Sulfur										66		66
Particulates	90	2		3							PP	
Trace elements[g]	4	<1	<1	2				50	200	940		1132
Others									2577[c]			2577[c]
Total liquid/solid flowrate, lb/h	597	1	1033	497683	2413000	10000	1179700	883447	23727	303561	25500	147802
TOTAL STREAM FLOWRATE, lb/h	597	165	1033	6942675	2413000	10000	1179700	883447	23727	303561	25500	147802
Radioactivity[h]	2.6			0.05					2.5	~2.5		2.5

Footnotes are given at the end of the table.

TABLE A-1 (CON'T)

Component		Stream Number									
		37	38	39	40	41	42	43	44	45	46
FLOWRATE, lb mol/h											
CO	28.01										
CO_2	44.01			< 1	< 1			2			2
H_2	2.02										
CH_4	16.04										
C_2H_4	28.05										
C_2H_6	30.07										
N_2 + inerts	28.01			< 1	< 1						
O_2	32.00										
H_2S	34.08							< 1			< 1
COS	60.07										
H_2O	18.02										
Others											
Total gas flowrate, lb mol/h				2	2			3			3
Temperature, °F		70[a]	70[a]	393	393	170[a]	197[a]	160[a]	157	110	95
Pressure, psig		10[a]	10[a]	251	251	251	250	250[a]	100	80	50
FLOWRATE, lb/h											
H_2O		139579	878977	98623	982625	340413	216938	1992989	2347		1990642
Methanol											
Tar				3188	31873	3603	835	36311	36311		
Oil				1344	13444	31221	7246	51911	2	51709	200
Naphtha				pp	pp	pp	pp	pp	pp	pp	pp
Crude phenols				996	9959	4248	986	15193	pp		15193
Mercaptans[d]				2	20	10	4	39	39	pp	pp
Thiophenes[d]				1	19	8	4	34	34	pp	pp
Ammonia				173	1734	6490	1507	9808			9808
HCN[d]				pp	pp	3	1	4	pp	2	2
Aromatic amines[e]				pp	pp	1	< 1	2	pp	1	1
Nitrosamines[e]				pp	pp	1	< 1	2	pp	1	1
PNA				7	78	1	1	80	78	2	pp
Fatty acids				177	1770	835	194	8268			8268
$Ni(CO)_4$[f]						3	1	5	1	1	
Minerals		413	2600								
Coal											
Sulfur											
Particulates				410	4108			4108	4108		
Trace elements[g]		8	50	< 1	5			5	5		pp
Others											
Total liquid/solid flowrate, lb/h		140000	881627	104562	1045635	386837	227719	2118759	42925	51716	2024115
TOTAL STREAM FLOWRATE, lb/h		140000	881627	104634	1045707	386837	227719	2118881	42925	51716	2024237
Radioactivity[h]											

Footnotes are given at the end of the table.

TABLE A-3 (CON'T)

Component		Stream Number									
		47	48	49	50	51	52	53^{a}	54^{a}	55	56	57
FLOWRATE, lb mol/h												
CO	28.01									134	134	
CO_2	44.01		2		2	314				33646	33646	
H_2	2.02									171	174	
CH_4	16.04										411	
C_2H_4	28.05									65	65	
C_2H_6	30.07									337	338	
N_2 + inerts	28.01					11633				1	1	
O_2	32.00					2704				14		
H_2S	34.08		< 1		< 1	pp				157	2	
COS	60.07									2	2	
H_2O	18.02											
Others						2^{p}					14^{i}	
Total gas flowrate, lb mol/h			3		3	14653				34527	34787	
Temperature, °F		266	95	95	130	Amb.	80^{c}	70^{c}	80^{c}	95	95	58
Pressure, psig		130	157	300	50	Atm.	10^{c}	100^{c}	10^{c}	12	6	390
FLOWRATE, lb/h												
H_2O		452	1990190	40	1990190	13981	1961947	27855	2813069	764	41992	2420
Methanol										463	461	
Tar												
Oil		200	pp		pp		pp	pp	pp			pp
Naphtha		pp	pp		pp		pp		pp			pp
Crude phenolic		14606	587		587							
Mercaptans^{d}		pp	pp		pp					pp		5
Thiophenes^{d}		pp	pp		pp					pp		3
Ammonia			9808	8521	1287		pp			4	4	60
HCN^{e}		2	pp							3		1
Aromatic amines^{e}		1	pp		pp		pp	pp	pp	pp		3
Nitrosamines^{e}		1	pp		pp		pp	pp	pp	pp		2
PNA		pp	pp		pp		pp	pp	pp	pp		pp
Fatty acids			8268		pp		pp	pp	pp	pp		pp
$Ni(CO)_4$^{f}										3	3	
Minerals								2100	500			
Coal												
Sulfur												
Particulates												
Trace elements^{g}								45	5			
Others											61^{m}	
Total liquid/solid flowrate, lb/h		15262	2008853	8561	2000292	13981	1961947	30000	2813574	1237	42571	2490
TOTAL STREAM FLOWRATE, lb/h		15262	2008975	8561	2000814	440296	1961947	30000	2813574	1503999	1546631	2494
Radioactivity^{h}										0.05	0.05	

Footnotes are given at the end of the table.

TABLE A-3 (CON'T)

Component	Stream Number										
	58	59	60	61	62	63	64	65	66	67	68
FLOWRATE, lb mol/h											
CO 28.01						pp			< 1		< 1
CO_2 44.01						pp	< 1		2360	2	1635
H_2 2.02							2		30		3
CH_4 16.04							5		54		48
C_2H_4 28.05							1		< 1		< 1
C_2H_6 30.07									2		1
N_2 + inerts 28.01									5235		< 1
O_2 32.00									177		
H_2S 34.08						pp	2		< 1		
COS 60.07						pp					
H_2O 18.02								125	1353	< 1	
Others							1^{m}		$< 1^{m}$		$< 1^{m}$
Total gas flowrate, lb mol/h							12	125	9215	3	1691
Temperature, °F	130	100	100	Amb.	Amb.	Amb.	100	212	600	200	95
Pressure, psig	100	220	100	Atm.	Atm.	Atm.	12	Atm.	8	Atm.	8
FLOWRATE, lb/h											
H_2O	450593	450593		762							
Methanol		374									1830
Tar											
Oil	pp	pp									
Naphtha	pp	pp									
Crude phenols	pp	pp									
Mercaptans [d]											
Thiophenes [d]											
Ammonia	17	17									
HCN [e]											
Aromatic amines [e]	pp	pp									
Nitrosamines [d]	pp	pp									
PNA	pp	pp									
Fatty acids	pp	pp									
$Ni(CO)_4$ [f]						2^{c}					
Minerals											
Coal											
Sulfur											
Particulates											
Trace elements											
Others	5469^{m}	26703^{r}	21234^{m}	6854^{g}	2480^{g}	2480^{g}					
Total liquid/solid flowrate, lb/h	456079	477687	21234	7616	2480	2482					1830
TOTAL STREAM FLOWRATE, lb/h	456079	477687	21234	7616	2480	2482	286	2253	281652	106	74699
Radioactivity [h]											

Footnotes are given at the end of the table.

Footnotes for Tabel A-1

[a] Most but not all of the values reported in the Table were developed from information obtained from the Mobil report by Schreiner 165. Stream numbers in the table correspond to stream numbers in Figure 2-1.

The information given in the table is very preliminary in nature. No warranty on the accuracy of the values reported is intended or implied.

Blanks in the table indicate that the components are not likely to be present.

[b] Amb. = ambient temperature; Atm = atmospheric pressure.

[c] Estimated value.

[d] Estimated values. Values reported for streams 7-9 are estimated based on information from refs. 57 and 165; values for the other streams were developed based on process design considerations.

[e] Estimated values. Values reported for streams 7-10 are estimated based on information from refs. 57, 74, and 165; values for the other streams were developed based on process design considerations.

[f] Estimated values. Values reported were developed based on process design considerations and on information given in ref. 57.

[g] Trace elements likely to be present include Ag, As, B, Ba, Be, Cd, Co, Cr, Cu, F, Hg, Li, Mo, Mn, Ni, Pb, Sb, Se, Sn, Th, U, V, Zn. The values reported are estimated values developed based on information obtained from refs. 74 and 109 and on process design considerations.

[h] Reported as parts per million (by weight) of Uranium and Thorium. Values reported are estimated values based on information reported in ref. 109 and on process design considerations.

[i] Methanol

[j] pp = probably present; however, insufficient information available for quantification. For analysis purposes, a value of 1 lb/h or 1 lb mol/h (as appropriate) may be used, if necessary.

[k] Values reported are developed based on the coal analysis and on information obtained from ref. 74.

[l] Stream composition developed based on information obtained from ref. 57.

[m] See Table A-2 for more detailed breakdown.

[n] Consists of 15 lb mol/h of SO_x and 4 lb mol/h of NO_x.

[o] Sludge

[p] Sulfur Dioxide

[q] Estimated values.

[r] Consists of ethanol, heavy alcohols, fatty acids, aldehydes, and ketones.

[s] Iron ore. Used to manufacture proprietary catalyst for the Fischer-Tropsch process.

Table A-2. DETAILED BREAKDOWN OF LIQUID HYDROCARBONS IN SELECTED STREAMS GIVEN IN TABLE A-1

Component		Stream Numbers[a]												
		17	18	19	20	21	22	23	56	58	60	64	66	68
FLOWRATE, lb mol/h														
C_2H_6	30.07			1.06										
C_3H_6	42.08	745.30	189.49	17.71									0.50	0.50
C_3H_8	44.09	124.45	18.25	168.12					0.18			0.18	0.07	0.05
l C_4H_8	56.10	400.30	0.24		1.55	4.68								
i C_4H_8	56.10													
i C_4H_{10}	58.12	2.60	0.06			1.32								
n C_4H_{10}	58.12	49.33	0.03		19.93	89.05			0.83			0.83		
l C_5H_{10}	70.13	231.22	0.04			7.55								
i C_5H_{10}	70.13													
i C_5H_{12}	72.15	9.90				305.63								
n C_5H_{12}	72.15	29.71	0.01			55.53	0.02		0.07			0.07	0.14	
l C_6H_{12}	84.16	152.51	0.01											
i C_6H_{12}	84.16					173.67								
i C_6H_{14}	86.17	11.17	0.01			30.72	0.02							
n C_6H_{14}	86.17	26.08	0.01				0.05							
C_6^+ C_7^+[b]		587.88	0.65				129.70	22.81						
Alkylate	102.51					332.07								
Cat. poly gasoline	118.15					350.88								
Acids	63.24									86.48				
Ethanol	46.07										254.61			
Heavy alcohols	64.69										146.92			
Total, lb mol/h		2370.45	208.80	186.89	21.48	1351.10	129.79	22.81	1.08	86.48	401.53	1.08	0.71	0.55
Total, lb/h		185977	8903	8190	1245	124862	25390	7436	61	5469	21234	61	34	23
C_7^+ mol. wt.		150.6	153.24				195.70	326.00						

[a] Stream numbers indicated correspond to stream numbers in Figure 2-1 and Table 2-3

[b] See below for component molecular weight.

Additional Remarks

The following additional remarks should be noted regarding unnumbered streams in Figure 2-1:

1. The composition of the lockhopper vent gas from the coal lockhopper is expected to be the same as the gas phase composition of the raw gas exiting the gasifier (stream 7); the volume of course will be considerably less than the raw gas flow rate.

2. The lockhopper vent gas from the ash lockhopper is essentially composed of steam and ash particulates. As shown in Figure 2-1, this stream is generally scrubbed with water prior to discharge to the atmosphere. The vent to the atmosphere from the scrubber will essentially consist of water vapor and air.

3. The reader is cautioned that Figure 2-1 is a simplified block flow diagram. For simplicity sake many interconnections between the units shown have been deleted. However, care was exercised to include all streams of potential environmental concern. Because of the above simplification, streams around individual units shown in Figure 2-1 may not always balance. Efforts to determine stream compositions for intermediate streams at various units based on the information given in this analysis is discouraged.

4. The biosludge from the biological treatment unit is likely to contain potentially hazardous organics. Following discussions with some of the assessment participants, its fate is shown in Figure 2-1 as "to disposal"--presumably in and environmentally acceptable landfill operation along with the gasifier ash. An alternative disposition may be to dispose of the organics-laden biosludge in the gasifier along with the feed coal. The biosludge will have a negligible effect on the feed coal or gasifier operations (considering its relatively insignificant flow rate when compared with the feed coal flow rate) while the suggested procedure will eliminate a potential environment concern. However, the viability of the suggested option may need to be demonstrated.

5. In Figure 2-1, a reverse osmosis treatment step has been shown following the biological treatment of the wastewater. The above step is an addition to the treatment scheme reported by Schreiner[165]. Reverse osmosis treatment is used to remove mainly metal salts from the treated water. In the process, the metal salts are removed as a concentrated waste solution which is disposed of appropriately. Again, following discussions with some of the assessment participants, it was decided to leave the disposition of the waste solution open. Possible disposition methods may be deep well disposal (local environmental regulations permitting) or evaporation ponds.

6. The reverse osmosis process is used in the present analysis as an example process. Another potential route is the use of multi-effect evaporators. The evaluation of alternative processes is beyond the scope of the present assessment.

7. Fugitive emissions are likely to occur from product and by product storage tanks. The likely compositions of the emissions will reflect the product or by product stored in the tank(s). The release of fugitive emissions are not addressed in this analysis.

8. Information was sought on the analysis of leachates from dry-ash Lurgi ash piles, but none was forthcoming[69].

TABLE A-3

ESTIMATED PROBABILITY OF RELEASE OF HYPOTHETICAL FACILITY STREAMS

STREAM NUMBER	STREAM NAME	SOURCE	PLANT[a] AREA	STREAM TYPE							ESTIMATED[c] POTENTIAL FOR RELEASE
					DESIGNED AS INTERNAL STREAM						
				DESIGNED[b] TO BE RELEASED	TEMPERATURE °F	PRESSURE (psig)	CORROSIVE MATERIALS	LEAK/FAILURE PRONE COMPONENTS	HOUSEKEEPING REQUIREMENTS	MAINTENANCE REQUIREMENTS	
1	Feed Coal	Coal Pile	A		Ambient	Atm.	L	M	H	M	L
2	Sized Coal	Coal Preparation	A		Ambient	Atm.	L	L	H	M	L
3	Undersized Coal	Coal Preparation	A		Ambient	Atm.	L	L	H	M	H
4	Oxygen	Air Separation	H		290	480	M	M	L	M	L
5	Nitrogen	Air Separation	H	X	Ambient	Atm.	L	M	L	M	H*
6	Steam	Utilities Generation	H		748	660	M	H	M	M	M
7	Raw Gas	Gasifier	B		900	450	H	H	H	H	H
8	Washed Gas	Wash Cooler	B		700	445	H	M	M	M	L
9	Cooled Gas	Waste Steam Generator	B		400	425	H	M	M	M	L
10	Gas	Gas/Liquor Separator	B		367	414	M	M	H	M	L
11	Gas	Gas Recompression/ Separator	B		367	414	M	M	H	H	M
12	Gas	Gas/Liquor Separator	B		367	414	M	M	H	M	L
13	Cooled Shifted Gas	Gas Cooling	B		86	400	L	L	M	M	L
14	Cooled Gas	Gas Cooling	B		86	400	L	L	M	M	L
15	Combined Gas	14 and 13	B								
16	Purified Gas	Rectisol Unit	C		68	348	L	M	M	M	M
17	Fischer-Tropsch Products	Fischer-Tropsch Synthesis	D		100	248	H	M	H	H	M
18	SNG	F-T Product Upgrading	E		130	1000	M	M	M	M	M
19	C_3LPG	F-T Product Upgrading	E		100	350	L	L	L	M	L
20	C_4LPG	F-T Product Upgrading	E		100	146	L	L	L	M	L
21	Gasoline	F-T Product Upgrading	E		100	142	M	L	M	M	M

TABLE A-3 (CON'T)

STREAM NUMBER	STREAM NAME	SOURCE	PLANT[a] AREA	STREAM TYPE							ESTIMATED POTENTIAL FOR RELEASE
				DESIGNED[b] TO BE RELEASED	DESIGNED AS INTERNAL STREAM						
					TEMPERATURE °F	PRESSURE (psig)	CORROSIVE MATERIALS	LEAK/FAILURE PRONE COMPONENTS	HOUSEKEEPING REQUIREMENTS	MAINTENANCE REQUIREMENTS	
22	Distillate Fuel Oil	F-T Product Upgrading	E		130	100	M	L	M	M	M
23	Heavy Fuel Oil	F-T Product Upgrading	E		130	100	M	L	M	M	M
24	Fugitive Emissions	Coal Preparation	A		Ambient	Atm.	L	M	H	L	H
25	Coal Dust	Bag House	A		Ambient	Atm.	M	M	H	L	H
26	Vent Gas	Bag House	A	X	Ambient	Atm.	L	L	M	L	H*
27	Coal Pile Leachate	Coal Preparation	A		Ambient	Atm.	M	-	H	-	H
28	Stack Gas	Utilities Generation	H	X	200	Atm.	L	L	L	L	H*
29	Evaporative Losses	Utilities Generation	H	X	Ambient	Atm.	L	L	L	L	H*
30	Deaerator Losses	Utilities Generation	H	X	Ambient	Atm.	L	L	L	L	H*
31	Makeup Water		H		60	5	L	L	L	L	L
32	Blowdown	Utilities Generation	G		70	5	L	L	L	M	L
33	Ash & SO_2 Scrubber Sludge	Utilities Generation	H		70	5	H	M	H	H	H
34	Ash Slurry	Ash Lockhopper	B		180	10	L	L	H	H	L
35	Vent Gas	Ash Handling	G	X	Ambient	Atm.	L	L	M	M	H*
36	Ash	Ash Handling	G		Ambient	Atm.	L	M	H	M	H*
37	Sluice Water	Ash Handling	G		70	10	L	M	M	M	M
38	Sluice Water	Ash Handling	G		70	10	L	M	M	M	M
39	Gas Liquor	Waste Steam Generator	B		393	251	H	M	M	M	M
40	Gas Liquor	Waste Steam Generator	B		393	251	H	M	M	M	M
41	Gas Liquor	Gas Cooling	B		170	251	M	M	M	M	M
42	Gas Liquor	Gas Cooling	B		197	250	M	M	M	M	M
43	Gas Liquor	(40,41,42,57,58)	X		160	250	M	M	M	M	M
44	Tars	Tars/Oil Separator	B		157	100	L	L	L	M	L

TABLE A-3 (CON'T)

STREAM NUMBER	STREAM NAME	SOURCE	PLANT[a] AREA	STREAM TYPE								ESTIMATED POTENTIAL FOR RELEASE
				DESIGNED[b] TO BE RELEASED	DESIGNED AS INTERNAL STREAM							
					TEMPERATURE °F	PRESSURE (psig)	CORROSIVE MATERIALS	LEAK/FAILURE PRONE COMPONENTS	HOUSEKEEPING REQUIREMENTS	MAINTENANCE REQUIREMENTS		
45	Oils	Tar/Oil Separation	B		110	80	L	L	L	M		L
46	Oil/Tar-Free Liquor	Tar/Oil Separation	B		95	50	H	M	M	M		M
47	Phenols	Phenol Recovery	F		266	130	L	M	L	M		M
48	Phenol-Free Liquor	Phenol Recovery	F		95	157	L	M	M	L		M
49	Ammonia	Ammonia Recovery	F		95	300	L	M	L	M		M
50	Ammonia-Free Liquor	Ammonia Recovery	F		130	50	L	M	M	M		L
51	Waste Air	Biological Treat-Treatment	F	X	Ambient	Atm.	L	L	L	M		H*
52	Biological Effluent	Biological Treatment	F		80	10	L	M	M	M		H
53	Concentrated Waste	Reverse Osmosis	F		70	100	H	M	H	M		H*
54	Treated Effluent	Reverse Osmosis	F		80	10	L	L	L	M		L
55	Sour Gas	Rectisol Unit	C		95	12	M	M	M	M		M
56	Incineration Gas	Stretford Unit	C		95	6	M	L	L	M		L
57	Waste Liquor	Rectisol Unit	C		58	390	H	M	M	M		M
58	Waste Liquor	Alcohol Recovery	E		130	100	M	M	M	M		M
59	Aqueous Liquor	F-T Synthesis	D		100	220	M	M	M	H		M
60	Heavy Alcohol Product	Alcohol Recovery	E		100	100	L	M	M	M		M
61	Catalyst Raw Material		D		Ambient	Atm.	L	L	H	L		M
62	F-T Catalyst	Catalyst Preparation	D		Ambient	Atm.	H	L	H	L		M
63	Spent F-T Catalyst	F-T Synthesis	D		Ambient	Atm.	M	M	H	L		H
64	Off Gas	F-T Product Upgrading	E		100	12	M	L	L	L		L
65	Waste Stream	F-T Product Upgrading	E	X	212	Atm.	L	L	L	M		H*

TABLE A-3 (Concluded)

STREAM NUMBER	STREAM NAME	SOURCE	PLANT[a] AREA	STREAM TYPE								ESTIMATED POTENTIAL FOR RELEASE
				DESIGNED[b] TO BE RELEASED	DESIGNED AS INTERNAL STREAM							
					TEMPERATURE °F	PRESSURE (psig)	CORROSIVE MATERIALS	LEAK/FAILURE PRONE COMPONENTS	HOUSEKEEPING REQUIREMENTS	MAINTENANCE REQUIREMENTS		
66	Heater Stack Gas	F-T Product Upgrading	E		600	8	L	L	L	L		L
67	CO Purge Gas	F-T Product Upgrading	E	X	200	Atm.	L	L	L	L		H*
68	CO_2 Off Gas	F-T Product Upgrading	E		95	8	L	L	L	L		L
69	Leachate from Ash	Ash/Scrubber Sludge	G		Ambient	Atm.	H	H	H	L		H
70	Biological Sludge	Biological Treatment	F	X	70	Atm.	L	L	M	H		H
71	Leachate from Biosludge	Biological Sludge	G		Ambient	Atm.	L	H	H	L		H
72	Lockhopper Vent Gas Emissions	Coal Lockhopper	B	X			H	H	L	H		H
73	Evaporative Losses	Product Storage	H	X			L	L	L	L		H
74	Evaporative Losses	Alcohol Storage	H	X	Ambient	Atm.	L	L	L	L		H
75	Evaporative Losses	Lurgi Oil Storage	H	X	Ambient	Atm.	L	L	L	L		H
76	Evaporative Losses	Lurgi Tar Storage	H	X	Ambient	Atm.	L	L	L	L		H
77	Evaporative Losses	Phenol Storage	H	X	Ambient	Atm.	L	L	L	L		H
78	Evaporative Losses	Ammonia Storage	H				L	L	L	L		L
79	Spent Shift Catalyst	Shift Reactor	B	X	Ambient	Atm.	L	L	L	L		H

[a] A - Coal Preparation
B - Gasification
C - Gas Purification and Byproduct Recovery
D - Fischer-Tropsch Synthesis
E - Fischer-Tropsch Product Upgrading and Storage
F - Waste Water Treatment
G - Solid Waste Treatment and Disposal
H - Utilities Generation

[b] Released directly to the environment

[c] Estimated potential for release
L - very small (negligible) possibility of release
M - moderate (fair-to-good) possibility of release
H - high (almost certain) possibility of release

* A designed release, certain to occur

TABLE A-4
ESTIMATED CONSTITUENTS OF FACILITY STREAM WITH HIGH OR MEDIUM PROBABILITY OF RELEASE

	DESIGNED RELEASES									HIGH PROBABILITY OF RELEASE																		MEDIUM PROBABILITY OF RELEASE																									
	GASEOUS									AQUEOUS					SOLID				GASEOUS									AQUEOUS																			SOLID		GASEOUS				
	5	26	28	29	30	35	51	65	67	27	52	53	69	71	3	33	63	79	7	24	25	72	73	74	75	76	77	17	21	22	23	37	38	39	40	41	42	43	46	47	48	49	57	58	59	60	61	62	6	11	16	18	55
TRACE ELEMENTS		√	√	√						√		√	√	√	√	√		√	√	√	√	√						√				√	√	√	√			√	√											√	√		
ALIPHATICS, ALICYCLICS AND FATTY ACIDS				√							√	√							√			√	√	√				√						√	√	√	√	√	√		√		√	√	√					√			√
BENZENE AND SUBSTITUTED BENZENES				√							√	√							√			√			√																												
PHENOLS				√															√			√			√	√	√	√						√	√	√	√	√	√	√	√			√	√					√			
POLYNUCLEAR AROMATIC HYDROCARBONS				√						√	√	√	√	√					√			√			√	√		√		√	√			√	√	√	√	√	√	√	√		√	√	√					√			√
SULFUR HETEROCYCLICS																			√			√			√									√	√	√	√	√	√	√	√		√							√	√		√
NITROGEN HETEROCYCLICS				√							√	√							√			√																															
OXYGEN HETEROCYCLICS				√							√	√							√			√				√																											
MERCAPTANS				√							√	√							√			√												√	√	√	√	√	√	√	√		√	√	√					√	√		√
AROMATIC AMINES				√						√	√	√							√			√												√	√	√	√	√	√	√	√		√	√	√					√			√
NITROSAMINES				√						√	√	√							√			√												√	√	√	√	√	√	√	√		√	√	√					√			√
AMMONIA											√								√			√												√	√	√	√	√	√		√	√	√	√	√					√	√		√
CARBON MONOXIDE																	√		√			√						√																						√	√	√	√
METHANE																			√			√	√					√																						√	√	√	
HYDROGEN SULFIDE							√										√		√			√																√	√		√									√			√
CARBONYL SULFIDE																	√		√			√																												√			√
NICKEL CARBONYL																	√		√			√														√	√	√												√	√	√	√
HYDROGEN CYANIDE																			√			√												√	√	√	√	√	√	√	√		√							√			√
TARS																			√			√												√	√	√	√	√	√											√			
OILS											√	√							√			√						√						√	√	√	√	√	√	√	√		√	√	√					√			