

DE84013989



ASSESSMENT OF TRACE CONTAMINANTS FROM A MODEL INDIRECT LIQUEFACTION FACILITY. VOLUME III. ECOLOGICAL HAZARDS OF LURGI/FISCHER-TROPSCH COAL LIQUEFACTION

OAK RIDGE NATIONAL LAB., TN

JAN 1982



U.S. Department of Commerce National Technical Information Service

DOE/EV/10291-- T2-Vol.3

Report 1234-03-81-CR

DE84013989

DOE/EV/10291--T2-Vol.3

DE84 013989

Assessment of Trace

Contaminants From a Model

Indirect Liquefaction Facility

VOLUME III – ECOLOGICAL HAZARDS OF LURGI/FISCHER-TROPSCH COAL LIQUEFACTION

Prepared By:

G.K. Eddlemon

Environmental Sciences Division Oak Ridge National Laboratory Oak Ridge, Tennessee 37830

January 1982

MANAGEMENT SYSTEMS DIVISION



CORPORATION

A SUBSIDIARY OF FLOW GENERAL INC. 7655 Old Springhouse Road, McLean, Virginia 22102

. NOTICE

DRTIONS OF THIS REPORT ARE ILLETIBLE. It is been reproduced from the best available py to permit the broadest possible availility.

Prepared For:

Technology Assessment Division Environmental Protection, Safety, and Emergency Preparedness Office U.S. Department of Energy

DISTRIBUTION OF THIS DUCUMENT IS UNLIMITED

Under Contract No. DE-AC01-79-EV10291

FOREWARD

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

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

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

This study was sponsored by the Technology Assessment Division of the Department of Energy. Organizations participating in the assessment were General Research Corporation, Oak Ridge National Laboratory, and Argonne National Laboratory.

TABLE OF CONTENTS

÷-

ب

i

	Page
2	:
LIST OF TABLES	ii
EXECUTIVE SUMMARY	i11
1 INTRODUCTION	1
2 AQUEOUS EMISSIONS 2.1 Ash and Ash Leachate (Streams 36 and 69 2.2 Reverse Osmosis Concentrated Waste (Str 2.3 Biosludge (Stream 70)) 2 eam 53) 12 21
 GASEOUS EMISSIONS 3.1 Utility Stack Gas (Stream 28) 3.2 Evaporative Emissions and Cooling Tower (Stream 29) 	28 28 Drift 35
3.3 Lockhopper Vent Gas Emissions (Stream 7	2) 37
4 SUMMARY AND CONCLUSIONS	42
5 REFERENCES	
APPENDIX	A-1

-

LIST OF TABLES -

12

Table Number

- 2-1 Gasifier Ash Leachates (Streams 36 and 69): Comparison of Projected Post-Dilution Environmental Concentrations (of Westfield Coal Ash Leachate) with Ecological Benchmarks
 2-2 "Worst Case" Gasifier Ash Leachates (Stream 69): Comparison of Projected Post-Dilution Environmental
 - Comparison of Projected Post-Dilution Environmental Concentrations of Substances in a Hypothetical Leachate that have the Highest Concentration Found in a Literature Search of Leachates from Gasifier Ash (Regardless of Coal or Specific Process) with Ecological Benchmarks
- 2-3 Reverse Osmosis Waste (Stream 53): Comparison of Projected Post-Dilution Environmental Concentrations of Trace Elements with Ecological Benchmarks
 - 2-4 Reverse Osmosis Waste (Stream 53): Comparison of Projected Post-Dilution Environmental Concentrations of Organics with Ecological Benchmarks
 - 2-5 Biosludge (Stream 70): Comparison of Projected Post-Dilution Environmental Concentrations with Ecological Benchmarks
 - 3-1 Utility Stack Gas Pollutants (Stream 28): Comparison of Projected Post-Dilution Environmental Concentrations with Ecological Benchmarks
 - 3-2 Stream 28 (Utility Stack Gases): Impacts of Trace Elements on Soils
 - 3-3 Cooling Tower Evaporative Losses and Drift (Stream 29): Estimated Emission Rates of Expected Contaminants 36
 - 3-4 Lockhopper Vent Gas Emissions (Stream 72): Comparison of Projected Post-Dilution Environmental Concentrations with Ecological Benchmarks
 38

Page

7

13

8

- 15

22

29

EXECUTIVE SUMMARY

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

⁽⁾ Where possible, these streams and their constituents were ranked according to their relative potential for adverse ecological effects. Streams or their constituents determined to be potentially harmful or inadequately characterized by available information are identified as worthy of further research.

Conclusions are tentative due to insufficiency of data regarding many key aspects of the assessment including: chemical, physical, and biological characteristics of facility streams; transformation and fate of stream contaminants; and characteristics of receiving ecosystems and ecosystem components. Perhaps the most serious constraint on the ability to evaluate potential ecological effects is the lack of knowledge regarding acute and chronic effects of whole stream emissions, and the synergistic, antagonistic, and additive interactions among constituents within streams and among streams. This need cannot be fully met until full-scale operating units produce waste streams that can be thoroughly characterized physically, chemically, and in terms of their biological and ecological activity.

iii

Given this consideration, several conclusions have been reached regarding ecological hazards posed by several facility streams:

- Gasifier and (utility ash and associated leachates should generate no serious, insurmountable ecological problems, although several trace elements and ammonia may pose problems.
- Effluent from the wastewater treatment unit is likely to contain toxic trace elements and organic compounds at
 concentrations which could pose a significant threat to aquatic ecosystems, and man though food chain contamination.

- Sludge from biological treatment of process wastewaters is likely to contain concentrations of trace elements and biorefractory compounds that would pose a hazard concentration ecosystems if the sludge is not disposed of properly.
- ----Cooling tower drift and evaporative releases appear to be the greatest atmospheric threat to local terresterial ecosystems due to the significant quantities of organic and inorganic contaminants released.
 - Utility stack gases may pose significant regional ecological hazards due to //release of sulfur oxides, nitogen oxides and trace metals, particularly mercury.
 - Final conclusions regarding ecological hazards posed by indirect liquefaction facilities cannot be made until a great deal more information regarding all aspects of ecological impacts become available.

ACKNOWLEDGMENTS

÷.

The author wishes to express his appreciation to Dr. Arnold Goldberg, President, INA Loss Control Services, Inc., formerly the DOE Project Officer, and Mr. Bipin Almaula, of the U.S. Department of Energy, for their assistance and guidance throughout the project.

Additional thanks is expressed for the close cooperation and useful suggestions of the many individuals involved in this project from Argonne National Laboratory (especially, Dr. Terry Surles and Mr. John Gasper), and Oak Ridge National Laboratory (especially, Dr. Kenneth Cowser, Dr. Phillip Walsh, and Dr. Suman Singh), and General Research Corporation (especially, Mr. Douglas Britt, Dr. Dexter Hinckley, and Mr. James Antizzo).

1 INTRODUCTION

This volume of the analysis is directed at the identification of those waste streams generated by the gasification phase of the indirect liquefaction process having a reasonable possibility of directly or indirectly entering the environment; evaluation of their effects on potential receiving ecosystems; and, where possible, ranking of these streams and their constituents by relative potential for adverse ecological effects. Waste streams or their constituents determined to be potentially harmful or inadequately characterized by available information are identified as worthy of further research. Neither the liquefaction phase of the process (Fischer-Tropsch), nor accidents per se are addressed here.

We have identified the following waste streams as potential or likely environmental polluters:

- Stream 36 (ash stream) and 69 (ash leachate).
- Stream 53 (concentrated waste solution from the reverse osmosis unit).

- Stream 70 (biosludge from the biological treatment unit).
- Stream 28 (stack gas emissions to atmosphere).
- Stream 29 (cooling tower evaporation losses to atmosphere).
- Stream 72 (lockhopper vent gas emissions).

Each waste stream is addressed individually in the following subsections. Because many of the assumptions, qualifications, and controlling variables apply to all of these streams, they are discussed once in Section 2.1 (Streams 36 and 69, ash and ash leachates). Those peculiar to a given stream are discussed in the section applicable to that stream.

2 AQUEOUS EMISSIONS

2.1 ASH AND ASH LEACHATE: Streams 36 and 69

The gasifier ash (Stream 34) and the utility boiler fly ash, bottom ash and scrubber sludge (Stream 33) are all consolidated into one large-volume stream (Stream 36) dominated by the gasifier ash. For this study, we have assumed the ash would be trucked off-site to a landfill. As shown in Volume II, Section 2.4, the resulting ash pile is estimated to yield an average leachate flow rate (Stream 69) of 0.85 liters per second (6644 lbs/hr or 0.030 cfs). Aside from the direct and total physical destruction of any ecological communities occupying the site of the ash pile itself, the major ecological hazard posed by the ash is the entry of these potentially toxic ash leachates into off-site aquatic ecosystems.

The nature and extent of the impacts on a receiving ecosystem will depend on the quality and quantity of the ash leachate entering that system. Leachate quality and quantity, in turn, will vary with a number of factors, among them:

- 1. Source coal composition and physical characteristics.
- 2. Specific type of proposed gasification processes and facilities.
- 3. Ash chemical and physical characteristics (dry ash, slag, density, permeability, degree of moisture saturation, presence of organic matter).
- 4. Biochemical environment in the ash pile (pH, alkalinity, redox potential, microflora).
- 5. Local meteorology, especially quantity and quality of precipitation.
- 6. Hydraulic distance to the water table and nearest surface water.

7. Chemical species present in leachate.

8. Permeability and cation exchange capacity of the intervening soil.

9. Sorptive capacity of the soil.

10. Dilutive capacity of the groundwater.

Once the leachate enters a surface water body, the effects on the aquatic ecosystem will depend on many of the above factors as well as:

1. Volume and rate of flow of receiving surface waters.

- 2. Physical variables, including temperature, hardness, pH, and alkalinity of receiving waters.
- 3. Quantity and sorptive capacity of organic matter, suspended solids and sediments.
- 4. Chemical precipitation and biochemical reactions.
- 5. Volatilization and photolysis.

6. Ambient contaminant concentrations.

- 7. Structure and function of the existing aquatic communities, including relative sensitivity of important resident species.
- 8. Extent of additive, antagonistic, and synergistic interactions among the several contaminants in terms of toxicity and chemical reactions.

It is evident from this partial listing of the multitude of factors controlling ash leachate quantity, quality, toxicity, and ecosystem response that impacts on aquatic systems will be site- and project-specific. Further, information critical to an evaluation of ecosystem impacts is lacking for most of these factors, particularly for indirect coal liquefaction processes using Wyoming sub-bituminous coals. Consequently, a preliminary evaluation of the hazards posed by ash piles requires a number of assumptions regarding the above controlling factors, and the use of data generated from similar processes and coals. Given these constraints, it is appropriate to make reasonably well-defined, conservative, (though not necessarily "worstcase" assumptions; e.g., the highest mean concentration of arsenic in leachates rather than the highest individual measurement found in any case, or a reasonably small 283 1/s (10 cfs) receiving stream vs. a 14 1/s (0.5 cfs) stream. For this evaluation, therefore, we have assumed the following:

- Leachate flow rate of 0.85 l/s (6644 lbs/hr or 0.030 cfs; see calculations, Volume II, Section 2.4).
- No attenuation of leachate contaminants by soil. This is a highly conservative assumption because soil attenuation will normally be an important mechanism for removal of contaminants.
- 3. Zero dilution of leachate prior to entry into receiving stream.
- 4. A moderately-small receiving stream flow of 283 1/s (10 cfs).
- 5. Sorption, precipitation, volatilization, photolysis, and other contaminant removal mechanisms in receiving streams are unimportant.
- 6. Two leachate types:
 - a) A leachate of gasifier ash obtained from the processing of Montana Rosebud coal in the modified dry ash Lurgi gasifier in Westfield, Scotland. This coal-process combination is more similar to the system assumed for this document than any other existing facility⁴¹ (Volume II, Section 2.4).

ţ,

- b) A hypothetical leachate having the highest observed concentration of each contaminant found in a literature search of leachates from gasifier ash (regardless of coal or specific process).
- 7. All leachate enters the 283 1/s (10 cfs) receiving stream.
- 8. Mean and highest exhibited toxicities (lowest toxic concentrations) regardless of end-point response (usually sublethal) or target species found in a literature search of gasifier ash leachates.
- 9. Negligible ambient concentrations of contaminants.
- 10. Negligible leachable organics.
- 11. No interactions among contaminants in terms of toxicity or chemical reactions.

Most of these assumptions contribute to the conservatism in the analysis intended in this evaluation. The last assumption, however, represents an important constraint on the validity of this analysis because additive, antagonistic, or synergistic interactions among the various toxic components of complex mixture are probable in nature. Unfortunately, an understanding of the interaction of toxic contaminants in complex mixtures must depend primarily on future research directed at actual samples obtained from operating facilities.

Other serious constraints on the validity of comparing toxicities of expected contaminant concentrations with each other and with various published toxicological results are the lack of standardization among testing procedures, exposure conditions, test organisms, and the uneven quality and quantity of research directed at the various contaminants. For example, some contaminants such as cadmium (Cd) or arsenic (As) may have been researched much more thoroughly than silver (Ag). Consequently, the apparently greater "worst-case" toxicities of Cd may be a reflection of the greater number of tests directed at Cd (on more sensitive organisms) than directed at Ag. Furthermore, length of exposure, water quality, and test animals may differ greatly among Ideally results of bloassays conducted under identical contaminants. test conditions and utilizing similar target species stall be compared However, with the exception of the chronic for each contaminant. toxicity data for Daphnia magna, this was rarely possible. The method of evaluating the potential hazards posed by ash disposal consisted of comparisons of contaminant concentrations in ash leachate after stream dilution with:

- 1. Ambient surface water concentrations.
- 2. Water quality criteria for protection of sensitive aquatic organisms.
- 3. Proposed ambient level goals for protection of aquatic life^{S-11} (estimated permissible concentrations for protection of aquatic life, EPC_{we}).

5 ·

4. The lowest reported concentration for each contaminant eliciting a response (generally sublethal).

5. The mean average of reported concentrations for each contaminant showing toxic (sublethal) levels.

6. Bioaccumulation threshold concentrations (concentrations of contaminants in freshwater which, if accumulated by fish according to reported bioaccumulation factors, would lead to the minimum body-burdens just toxic to man if consumed at a rate of 0.06 kg/day).

• • •

. ..

C

7. The concentration which elicits a chronic toxic response in Daphnia magna. (sometimes coincides with item 4, above).

Specifically, the ratio of each contaminant concentration in the leachate to the criteria concentration (contaminant/criterion) was computed. Contaminants were then listed with the magnitude of the ratios, the greater the value of the ratio, the greater the relative hazard posed by that contaminant. Tables 2-1 and 2-2 present the results of this procedure for 25 contaminants likely to occur in the gasifier ash leachates selected for analysis. With the exception of ammonia, all of the selected contaminants are trace elements. Other elements such as Ca and Mg, were not included in the analysis because of their apparently slight toxicity or because their presence has not been detected.

One admittedly rough indicator of relative potential hazard is the ratio of leachate concentration to ambient freshwater concentration for a given contaminant. Table 2-1 presents those ratios for the diluted Westfield leachate 41 and Table 2-2 presents them for the "worstcase" leachates.^{3,5,22,43,47,57} It is important to note that the weighted-mean ambient concentrations used to calculate these ratios represent the products of the mean observed values for each element and their precentage frequency of detection, as presented in Kopp and Kroner's (1967) 5 year summary of trace metals in freshwaters of the United States.²⁹ For some contaminants, such as cadmium, many surface waters yield no detectable concentrations. For the 11 trace elements measured, the Westfield after dilution leachate ranged from a high of GASTFIER ASh LEACHATES (Strenms 36 + 69): TABLE 2-1

. .

CONCENTRATIONS (OF Westfield coal ash leachare) WITH COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL ECOLOCICAL BENCHMARKS

N/18		2.7E-2	1.7E-2			2.0E-3	8.22-3		1,26-1	6.1E-2	5-0E-2	1.3E-2	3.55-2	9.AE-1		1.8£-4	
-	Auli tont Freshingfiy Cont. wg/1	2.3%-2	3.58-3	1.02-5	9.96-2	2.48-4.	1.18-2	•	1.95-2	4.42-3	1.06-2	7.02-54	1.11	2.06-4		4.95-2	
D/V	<i>.</i>	-	1.16-3			5.0E-1				2.15-2		1.48-2		·1.86-2			-
ų	Frujuaud Freshuur <mark>Fr</mark> Griteria E mµ/t		5.7E-2	1.78-4		1.88-4				1. JE-2		6.4E-5.	:	9.78-3			1
A/F		2.06-2	-1.25-2			9.58-4	4.55-1		4.88-2	4.56-2	5.08-1	1. 16 -2	5.56-3	9.06-2	-	4.4E.4	
54	flireshold Blouceq f j Cont. •K/f	3.06-2-	5.08-3	·		2.0E-1	2.08-2		1.06-1	6.0E-4	3.08-2	7.06-5	2.0E-2	E-:16.2		2.06-2	i
a/v		1.98-1	1.25-4			1.16-2	4.28-3	,	1.16-3	9.0E-3	3-66-4	2.74-4	3.68-3			1.2E-4	
क्ष •	Daphuta Chronte Tox{{{}_{*}}}	<u></u>	5.26-1			1.75-4	2.25-2		3,88-1	3.012-2	4.1	1.46-1	1.06-2			7.05-2	-
d/v ·		2.2E-4	2-05-5			- <u>5-48-5</u> .	9.05-5		5.96-4	1.56-4	1.26-4	1.08-4	3. TE-4	1.28.5		J.8E-6	1
a	Hean Toxie. (c) Gune. (k) Ng/k	2.7				1.58-2	9.58-1		H. 1	1.8	1.2611	9.116-1	J. 2K-1	2, 5k		2.3	1
N/C		8.6E-3	2.76-3	 		9.58-1	2, 38-1		2.48-2	9. OE-1	4.715-3	4.56-3	1-36-1	1.25-3		2.96-1	۱ :
Ľ	Jawest Observed Toxte (b) Conc. (b) mg/2	7.06-2	2. 2E-2			2.01:-4	4.118-4		2.(1E-1	3. 116-2	1.48-1	2.08-4	1.06-2	2.56-1		1.06-1	•
A/B		<u> </u>	6.01-5			4.8E-1	9.611-1		9.56-2	2.71:-2	1.5E-2	1.86-2	5,48-2	1.48-2		4.56-4	:
	Eff. (4) mg/t	2.06-1	1.06-2			4.0E-4	1.06-2		12-30.2	1. OE-2	2.01E 2	5.08-5	2.01.1	1.6	, ,	2-(0)-2	;
<	Ear Indies Post- dilution Gone.	6. OE-4	6.0E-5	1	· : 	1.98-6	9.0E-5		4.BE-1	2. 7E-4	1.3E-1	9,08-7	1.18-4	1.86-4		8./E-6	!
	_	The strength and a st	Arecolc		Burton	Cadadawa	Cupter	Fluid for	l rat	Lead	Hanganeru	Herrar y	Nickel	Selection	Vanadhut	21m	jorat. Tokie granints .

 $^{-3}$ Eatimated permissible concentration in aquatic ecosystem 34 .

^bitigardless of spectes, type.of response, or exposure conditions⁴⁹

: .

 $\zeta = c_F \omega r$ freshwater constaceans, unless otherwise noted 131

democration courted to parcent reproductive impairment after 3 weeks12

ł,

elleferance 130

206 $t_{\rm Assuming}$ hiorecommutation factor of 2.3, 1.4 and drinking water standard of 0.05 mg/f

Elleferences 209, 210 and 211

... > lyndenduted from mean ubserved punttion values trom U.S. Freshvaters, weighted according to frequency of detrection¹⁰⁶

¢

14550000 1420 - (0.2) (1475 of 0.250 mg/t)

Personul commutertaus: 6.1. Klugabury

kFor' phytoplanktoù

think and Widthe Service⁶²

:

TABLE 2-2

.

"MORET CASE" CASTVIER ASH LEACHATES (STREAN 60): CORPARISHED FOST DILUTIOR ERVIROHERTAL CONCENTRATIONS OF SURSTANCES IN A HYDOTHETCAL LEACHATE FOST DILUTIOR ERVIROHERTAL CONCENTRATIONS OF SURSTANCES IN A HYDOTHETCAL LEACHATE THAT LAVE THE HICHEST CONCLETINATION FORM IN A LITERATURE SEARCH OF LEACHATES FROM GASIFIER ASH (REGARDLESS OF COAL OR SPECIFIC PROCESS) NITH ECOLORICAL BENCINARS

•

	*	=	U	9/C	_	A/b	ĸ	A/E		AIA		A/G	=	N/N	-	IN
	Delining	Difaced			Lound		ti subuct a		Bires-		;		1			
	Burne	Armed Seela	; ;		liters wed		Jumb.				Toulr		Freda-		Veral.	
	- Ile	I.t.n. hult	f		I Toule,		Toulotty		1	:	Cour.		valet			
	I rarlinte	2		•	tour.								Griteria		Cour.	
			;		, ř						-x/r		=8/f C		-2 /l -	
- inititry	1-36-9	.6.0Ľ %	1-30.1.	1.5	1.0E-2	9.9	1.21.1	2.2	1.01-2	1.30.5	2.70	2.64.1		İ	2.35.2	1.061
ATT PARTY	1.16.)		1.05-2	4.58-2		1-49-1	:			1.16.1	2.0611	9-01-5			1.11.4	1481
AKSLUIC	9.06	6-08-5	1,415-2	1-30-6	2.25-2	4.18-1	5.4E 1	1.75-2	5.06-3		1.1	7.98-0	5.15.2			
ian uvi	1 35-1		5.02-1	1.05	5.8	2.62 4	R. (16 -1	2.76-4		1.06-4	1111.5	2-41-5	ļ	!	A. 76-2	
BUTTIAN IN	9,016-5	:	1.11-2	0.2K 1	1.52.1	6.08.4	;	;	1.1611	5.44-6	9.6=	9.2%-6	1.12.1	1-31-5	1.08-5	0.6
erikeria	1.11.1	:	5.0	2.11.5	1-26.4	1.64-1			1.5212	7.16-4	4.0E(1"	2.84-3		!	9.96-2	-
CALIFUL STATE	1. HE-4	1.71 6	7-36-7	1-35-1	2.08.4	9.06.1	1.12 1	1.1	2.05-3	\$,0E-2	3.52-2	5.1E-J	3.AE-4	1.36.4	2.46-4	1.36.1
innest i	§ .0E 4	!	5.tuE-2	1.21.1	5.01.2	1.78-1		1.85.1	4.05-4	1.5	9.9	6. Hr. 5		1	2.48-3	2.5%-1
Cultat I	1.11.1	:	2-10-2	1.18-2	1.01.2	5.11-2	1.01.2	5.11:2	5.0E-3	1.15-1	1.0	5. JE-4			A. HN-4	1.2
inita	1-22-1	9.06.5	1.06-2	1-22-1	4.415. 4	1.0	2 26-2	5.46-2	2:0C-2-	6.02-2	9.58-1	1.36-1			1.11/-2	1.18.1
HIMMINE			i			1./E.)					2.7512	1.15-5		2		;
		(3.016 - 1	5.261	2.411. J _	1.1611	1-38.1	6.02-1	1-30.1	3.661		1.25-1		!	1.96-2	6. /611
	4-30-4	2.12.4	1.05-2	6-08-2	3.01-2	2-40-5	3.08-2	2-0E-2	6-02-3	1-30.1	-	1.16-4	1.11-2	4.62-2	4.46.1	1-39-1
İstristati	1.16-2	1.35.1	2.0E.1	5.56-1	1.5%-1	1.16-2	(.)	1.86-3	1-70-1	1.7	1.2611	9.2E-4			3.06-2	1-37-1
IN-BOCORY	6. DE-6	1 311-6	5.0E-3	1.22.1	2.08-4	1.08-2	3.46-3	[J.B.]	7.02-5	8.ftE-2	1-30.9	6. /E-4	6.44-5"		7.01-5	R. 6E - 2
HUTULLIN	1.01	:	1.4	1.28.1	4. /81	6.00.5	!		1.7	(-21-1	1.260.0	2.52-5			2.31.2	1-31/-1
andi	2.18-3	1.15-4	2.01-1	1.1	1.08-2	1.16-2	1.06-2	1.58-2	2.08-2	1.26-1	3.24 1	1-37-4			1.1E-1	7.46.1
inverts	1.88-4	1.85.4	5.06-1	1. AE-2	1-35.7	1.78-4			2.06-1	9.UZ-2	2.5"	1.215 5	9.16-1	1-36-1	2.06-4	9.405
SULVEN	1 III III	:	5.08-1	6.01.1	1 00-1	1.05-2			1-31.1	4.25-5	4.41.2	6.AE-4	9.01E 6		1.11	- I. HK
iniirii	4.01.6	: ;	:		0.05-2	1.62 5 .	!				2.0	2.46-6	•	:	1.08.1	(. HL.)
	9-30-6	:	•	;	1.32.1	2.65-6	1-36-1	1.7E S	6.AE 4	1.51-2	1134-6	1.016-1			4.06.5	
เกินหน่น	5. IE-3	;	1.0.1	2-31.4	2.B	1.11-1				5.98-2	1.06110	1.16-4	;		1.0%-1	: - ~
- intrituiva	2.11.2	, ; ;	1.16	1.2%-1	(.u.,	5,01-1			1-31.1	2. JE-i	2.4411	1.0E-3			1.4%-1	1.761
inic	1-31-5	8./E É	2.06-2	/.h	1.05-3	1.1.1	1 16-2	1-31-1	2.06-2	2.6	1.2	2.2E-2			4.91-2	! -
AUTORIA	6.10.2		1.01.2		1.015			:	:		1.51	1.56.2			i	

,

.

÷,

· ·

.

8

,

0.9 times ambient concentrations for Se to a low of only 0.00018 times ambient for Zn; Fe, Pb, and Mn concentrations in the leachate were 0.12, 0.061 and 0.05 times ambient, respectively. It therefore appears that Se would rank first as an environmental concern on the basis of ambient conditions. However, differences in processes, feed coals, and physicochemical conditions, such as pH and other factors, may cause values for the concentration of trace elements in other gasifier ash leachates to Since only one set of values was available for the Westvary widely. field Lurgi gasifier/Montana Rosebud coal combination, and even this is not necessarily representative of the conditions assumed for this evaluation, we repeated the calculations using the highest ash leachate concentrations observed in our search of the literature, 3,5,22,43,47,57 Use of these "worst-case" values produces the ratios shown in Table 2-On the basis of their concentrations in "worst-case" leachates 2. relative to ambient concentrations, Fe, Al, V, Sb, and Be appear to be of greatest concern. A similar procedure was performed for comparisons of diluted (338:1) leachate concentrations with estimated permissible concentrations for aquatic ecosystems (EPCwe), mean crustacean texicity, lowest observed toxic concentrations, bioaccumulation thresholds. Daphnia chronic toxicity concentration, and proposed freshwater criteria.

None of the trace elements in the diluted Westfield leachate exceeded their respective EPC_{we} . Iron was closest, but still less than 10% of its EPC. On the basis of published worst-case concentrations, several inorganic contaminants exceeded their EPC's: iron, by a factor of 52; anmonia, 5.1; aluminum, 3.5; zinc, 2.6; and nickel by a factor of 1.1. It, should be noted that most of these EPC's were derived from either lowest reported $LC_{50's}$ (or TLm's), or standards and criteria.⁸

With regard to mean toxicities to freshwater organisms as compiled by Baird³³ or by Cushman¹⁴, no trace element in diluted Westfield leachate exceeds these concentrations. All trace elements occurred at less than 0.03% of their mean toxic concentration. With the exception of iron and aluminum, even worst-case concentrations are well below mean published toxic concentrations after dilution.

Copper (23% of lowest toxic concentration) was the only measured contaminant in the Westfield leachate that, after dilution, approached lowest observed concentrations eliciting a toxic response, regardless of type of response, species, or exposure conditions. All other measured ^s concentrations of contaminants were 1ess than 3% of their respective lowest observed toxic concentrations. If "worst-case" conditions were realized, zinc, iron, aluminum, copper, and possibly cadmium (in order exceed lowest • of decreasing toxicity) would observed toxic concentrations. Most of these lowest observed toxic concentrations, it should be noted, are based on chronic or sublethal effects. A better understanding of the relative, chronic toxicities of the several inorganic contaminants can be gained from columns, E and A/E in Tables 2-1 and 2-2. Column E shows the concentration of each contaminant found by Biesinger and Christensen (1972) to elicit a 16% reproductive impairment in Daphnia magna, a sensitive aquatic species, after 3 weeks exposure.² Column A/E presents the ratios of concentrations of contaminants in diluted Westfield and worst-case leachates to Biesinger and Christensen's (1972) chronic toxicity data.² None of the measured contaminants in the diluted Westfield leachate exceeded 1.1% of the chronic levels for Daphnia magna. In the worst-case leachates, aluminum and cadmium exceeded chronic levels by factors of 2.2 and 1.1, respectively, while zinc and iron occurred at only slightly less than chronic levels.

Tables 2-1 and 2-2 also present threshold bioaccumulation concentrations (TBC's) for each of the trace elements and the ratios of these concentrations to those in the diluted leachates. TBC's represent concentrations of contaminants in water which could accumulate to levels in fish tissue which in turn, might prove to be barely toxic when consumed by man. The TBC's used in this evaluation were computed by Hildebrand and Cushman²⁵ by the method of Dawson¹⁵, which is based on drinking water standards (DWS), published bioaccumulation factors, and the assumed human consumption of 0.06 kg of contaminated fish per day. The maximum safe daily intake by man was considered to be equivalent to

the quantity of the element represented by consumption of 2.0 for water containing the element at the DWS standard. From column A/F, it is evident that no measured contaminant in the diluted Westfield leachate exceeds its TBC. However, several elements in the "worst-case" leachate exceed their TBC's: iron, aluminum, manganese, zinc, arsenic, and chromium.

One contaminant would exceed its proposed EPA criterion level. In the "worst case" leachate values, silver was found to surpass proposed criteria levels by more than a factor of three. Cadmium and beryllium were also found to approach their EPA proposed criteria levels in the "worst case" leachate.

Once these contaminants have entered the receiving waters, they are unlikely to remain long at the modeled concentrations. Various physical, chemical, and biological transport and transformation processes commence immediately to remove trace elements from the water column. Many of the contaminants expected in the ash leachate may precipitate, sorb to sediments, volatilize, or otherwise disappear from the water column within a short distance of the source. As a result, contaminant enrichment of the sediments locally may produce conditions untenable for benthos in the immediate area of the source, but exposure downstream will be reduced significantly. Transport, transformation, and fate of many of the trace elements of most concern are summarized in the Appendix to this volume.

Organic contaminants are not expected to occur at appreciable levels in ash leachate. As would be expected for ashes from hightemperature gasification processes, several researchers presently investigating the composition and leachability of such ashes report little or no organic compounds in the leachate.⁶

Even under "worst-case" conditions, examination of the limited information at hand suggests that the ash stream leachates will generate no serious, insurmountable ecological problems. Should problems arise, the most likely causes would appear to be Cd, Al, Fe, Zn, and NH₃. This

evaluation unfortunately must leave unanswered the question of synergistic, antagonistic, and additive interactions among the several components of the whole leachate. Furthermore, unexpected contaminants may occur in the leachate. Final judgment regarding the degree of ecological hazard represented by this waste stream must await the results of rigorous chemical and toxicological characterizations of whole ash leachates (using representative, sensitive test species) from operating indirect coal liquefaction plants, followed by <u>in situ</u> monitoring of receiving waters. Certainly, the present state of knowledge concerning this waste stream calls for careful design, lining, and operation of ash disposal facilities.

2.2 REVERSE OSMOSIS CONCENTRATED WASTE (Stream 53)

Several disposal options for this 72 1/s (2.5 cfs) waste stream have been proposed including deep-well disposal and evaporation ponds. A properly designed, deep-well disposal system placed in an appropriate geological formation would effectively prevent entry of contaminants from this waste stream into ground or surface waters. Unfortunately, limited availability of appropriate geological formations and exisiting local regulations may prevent use of this method of disposal at a given site.

Appropriately sized and lined evaporation ponds would also effectively contain contaminants in this waste stream except for some limited volatilization of certain trace elements and organic residuals. However, groundwater must be closely monitored to ensure early detection of liner failure.

To facilitate comparisons of the relative ecological hazards represented by the many individual contaminants in this stream, as well as comparisons of the relative hazard of the whole waste stream with other streams from the model plant, we have assumed conservatively that the entire waste stream enters and is fully diluted in a small 283 1/s (10 cfs) freshwater stream (such as might occur at a completely inadequate disposal system). Tables 2-3 and 2-4 list those inorganic

TABLE 2-3

1

-

• . .

. -

•

1

REVERBL URIDSTS MASTE FLICAMS (STREAT 5.1); COUTARION OF PROJECTED POST-DILATION ENVIRONMALATAL CONCENTRATIONS OF THACE ELEMENTS ULTI FCOLOCICAL DENCHMARS ł -

ug gi Jaiking	A. hull 1. july 1.	2.1.1 2.1.1 2.1.1 2.1.1 1.1.1 2.1.1 1.1.1 2.1.1 1.1.1 2.1.1 1.1.1 2.1.1 1.1	2.08-2 2.08-2 2.08-2 2.00-2 1.0000-2 1.0000-2	5.28-1 	1.44%	2,26-2, 1,56-1, 1,76-4, 1,76-4, 2,1, 2,1, 2,1, 2,1, 2,1, 2,1, 2,1, 2,	4.0011 1.0011			5. 15. 5. 5. 15. 5. 1. 26. 6. 1. 4. 16. 7. 16. 16. 16. 16. 16. 16. 16. 16. 16. 16	9.4	1.56-1 1.56-1 1.966-5 2.46.4 2.46-1 5.46-1 5.46-1 1.46-1 1.46-1 1.46-1	6.601 1.2255 1.2255 1.2251 1.2251 1.2251 1.2251 1.2251 1.2251 1.2251 1.2251 1.2551
Musching 2, 15-1 1, 195-3 Marching 2, 15-1 1, 35-3 Marching 1, 25-1 2, 16-1 Marching 1, 27-1 2, 16-2 Marching 1, 27-1 2, 19-2 Marching 2, 2, 26-1 2, 09-2 Marching 2, 16-2 2, 09-2 Marching 2, 16-2 2, 09-2 Marching 2, 2, 16-2 2, 09-2 Marching 2, 16-2 2, 09-2	4, 14, 1 1, 16, 1 1, 16, 1 1, 16, 1 1, 1, 1, 1 1, 1, 1, 1 1, 1, 1, 1 1, 1,	2.11. 2.12.11. 2.12.12.11. 2.12.12.11. 2.12.11.11.2. 2.12.11.11.12.11.11.12.11.11.12.11.11.11	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	5.2k-1 5.2k-1 1.2k-4 1.2k-4 1.4k-3 5.4 1.4k-3 1.4k-3 1.4k-3 1.4k-3	(+48:1	2.75-2. 1.55-1. 1.55-1. 1.75-4. 1.75-4. 1.75-4. 1.95-2. 1.95-2.	1.0011 2.05-1 1.4. 1.4. 1.4. 1.4. 1.4. 1.4. 1.4. 1.		4.4841 2.3843 2.3842 1.1864 2.1842 1.1842	5.15.2 1.76-5 1.76-5	5.8 7.1612 1.4612 1.4612 1.4612	1.125-1 1.05-5 2.48-4 2.48-4 4.48-1 1.48-1 2.08-3 2.08-3 2.08-3 1.48-1	1.250 1.250 1.250 1.250 1.3 1.350 1.3 1.350 1.3 1.350 1.3 1.350 1.3 1.350 1.3 1.3500 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.35000 1.350000 1.350000 1.350000 1.350000 1.35000000000000000000000000000000000000
rey11ina [1.36.1] [1.36.1] [1.46.2] [1.	1.1501 1.1502	-9.0 -4.11811 3.55-2 1.55-2 1.1 2.7843 1.1 2.7843 1.1 2.7843 1.1 2.7843 1.1 2.7843 1.1 2.4841 1.1 2.4841 1.1 2.4841 1.1 2.4843 1.1 2.4844 1.1 2.4844 1.1 2.4844 1.1 2.4844 1.1 2.4844 1.1 2.4844 1.1 2.4844 1.1 2.48444 1.1 2.48444 1.1 2.48444 1.1 2.48444 1.1 2.48444 1.1 2.484444 1.1 2.4844444 1.1 2.4844444444444444444444444444444444444	P. 11.2.2.	1.1E:4		1,56-1. 6,96-1. 1,16-4. 1,16-4. 1,06-2. 1,356-4. 1,356-4. 1,356-4.	2. 05-13 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1		L-3K-3 L-3E-1 L-3E-1 L-3E-1 L-3E-1 L-2 L-2 L-2 L-2 L-2 L-2 L-2 L-2 L-2 L-2	1.16-6 1.16-6	2.1612	1.00-5 2.46-2 2.46-4 	1.2515 8.60. 9.7611 9.761 7.3 7.3 7.3 7.3 7.3 7.3 7.3 7.3 7.3 7.3
unun 1.42.1 3.4 ubdion 1.312-1 4.02-3 upper 1.312-1 4.02-3 upper 1.32-1 4.02-3 unu fage 1.32-1 1.02-2 unu 2.32-1 2.02-2 unu 2.02-2 2.02-3	1.46.4. 1.150.1. 1.120.1. 1.120.1. 1.120.1. 1.120.1.		P	1.28.40 - 1	14	4. JE-1 1. TE-4 2. 1 3. 55: 1 3. 55: 1 3. 56: 2 1. 0E-2	1.1 2.6612 2.6612 5.1612 5.1612 5.1612 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1	1,15812 1,208-3 	L.JE-1 6.2814 7.1814 1.1814	1.816 2.	1.4km2	2.46.4 2.46.4 	8.0 5.4607 9.2611 7.3 1.092 1.092 1.2511
ubelow 1.315-1 4.05-3 upper 0.3 0.3		2. 2. 16.2 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1		1,28:47 1,28:47 1,08:3	14612.	1.16-4	2.0412. 1.4 1.4 1.4 1.4 1.4 1.4 1.4 1.		6.3211	1.85 5	1.4812	2.46.4 9.016.2. 4.66.1 2.012.3 2.012.3 1.16.3 1.16.3	5.4617 9.2611 7.3 1.3 1.3 1.2511
upper	4.261 4.2614 4.2614 1.7611	2.782.1 1.0.2 1.0.1 2.06.1 2.06.1 2.06.1 2.56.1 1.12.1	1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.		14	2.1.1.0.2.1.1.0.2.1.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.1.0.2.2.2.2			1, TEL.	1.11 2.	1.4 1.4	1.4% I	1.2611 9.8 7.3 1.2511 1.2511
lunt tipe	4.1 4.2 4.2 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1	2.782. 1 1.0	1.144-2.1440-2.144-2.144-2.1444-2.144-2.144-2.144-2.144-2.144-2.144-2.1444-2.1444-2.1444-2.14440	5.1	1	2.1	4.05-5 4.05-2 5.05-2 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.	6.08:3 3.08:3 7.08:2 2.08:2	1.1217-	1.15 2	1.4	1.45.2 1.45.1 2.45.3 2.45.3 1.45.1 1.45.1	1.2611 7.3 1.0812 1.2611
oul	. 4.2012 . 4.2012 . 4.2012 . 1.9011	1.0	1.05-2. 1.05-2. 1.1.1. 1.1.1. 1.25-1.	1.04-2	14 14 15 15 15 15 15 15 15 15 15 15 15 15 15	1.06-2 - 1.55:1. 1.96-2.		6.08:3 1.08:3 1.08:5 2.08:2	1.2 1.7E()	4.15 2.	1.4	1-34.4 2.05.3 2.97.5 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 1.2.4 2.4 2.4 2.4 2.4 2.4 2.4 2.4 2.4 2.4	2.8 . 7.3 . 1.08:2 1.2611
od1.6.5.2 1.05-2 ngquete2.2.05-2 qegy2.16-2 5.95-2 titiet2.05-2.06-2	. 4.201. . 4.201. . 4.201.	1.0 1.241.1 3.06.3 3.06.3 3.26.1 3.26.1 3.26.1 3.26.1	1.1	1.04-2	4 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	05-2- 3,55:1. 1.98-2.		5.08-3 3.08-3 7.08-2	1, 1211	144 C	1.1 1.1 1.1	2.82.2 2.82.5 1.15.3 1.15.3	7.3
идиюнт2.26-1. 2.06-2 челиу2.16-2 5,935. Кімі1.065-2.1.2.06-3	. 4.201.	2.4F1	L]	6.1 1 1.46-3 1 1.46-	19852	3,55:4.		3.06-3 /.nk-5 2.06-2	1, 7ELL	<u>6.18.26.</u>	1. jeiz.	2,97,51 2,97,51 1,16-3	1.1 1.2511 1.2511
rirgiry 2.065.2 5:053. 11461 1.066.2 5:053.	. 1.2612.	3.0r.1 2	1-3E-1	3.46-3		1.06-2		7,0%-5	3,0212	•••••		1-27-2	1.2511 1.2511
li haj 1.86-2	1.9811	2.611	T - 32	3.01.2_1		1.0E-2		2.UE-2_				1-24-1	1.251
	4.07-3.	2.451	1.26				7.46-4		[1.42-1	1.2
rienium,	. 4.0r-3.						1.16.4						
anisticien					ļ	ĺ	•	1-1(-[1-34-1	 			
1115		-	:		•						; 1	1	
I'M. THACE FILTHURS			;;							;;			
INTIGAL ALACTOR US				••••				•					
			•						-	;	:	; ;	:
1 anuls: Ac fig			1					!	1	:	;		ł
ranjolr. Asld			! !		ļ				İ		•		
Heilylinitanis Acid			 							!	•	ļ	;
liethy ingumu te Actd'		:	!			1							İ
-utanok: AcM	·		<u>.</u>			İ	1		i	i			i
ralpineție. Ac 19			- - -		İ						;		
WW. LIVIT VCIIS													
ANAS & SUNSTRYNTED													
[hump]			. :		1	-	i				:		
ilylbruzenie	:			<u>نہ</u> ہر ز	 	;	ł		ļ	•			
utang	:		:				1	i		:	:		
	1		!	!							:		
. 2, 4 - Tr (mithy the jirkine			:			1		j		!	:		

•

13

.

ŗ

· ...

, ,

.

• `

TABLE 2-3 (Concluded)

^cConcentrations causing 16 percent reproductive impairment after 3 weeks exposure¹² b_{Nean} concentration toxic to freshwater crustaceans unless otherwise noted a Estimated permissible concentration for water, ecology 34 . :

×.;

 $^{\rm d}{\rm kegardless}$ of species, endpoint, conditions of exposure $^{\rm 49}$

^eReference 106

fkcference 89

^BAssumes hardness of water is 50 mg/l as $CaCO_3^{209}$,210,211

^hlnorganic mercury

.

TABLE 2-4

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

.

·		1		1 1		.1	
	A	В	А7в	C	A/C	D	A/D
	Estimated	Lovest		Lowest		EPCC	
	Post- Dilution	Observed LC ₅₀ ^a		Coserved Toxic ^b		 mg/1	
	mg/L	mg/1		Conc. mg/i			-
TRACE ELEMENTS						4	
Aluminum						<u> </u>	
Arsenic	<u></u>		· · · · · · · · · · · · · · · · · · ·				·····
Bervilium	N:						
Boron							
Cadmium				Ì	:		
Copper							
Fluorine	<u>.</u>		·				
Iron			•				•
Lead							
Manganese	·	1				• •	_
Hercury							
Nickel							
Selenium							
Vanadium]						
Zinc .							
TOTAL TRACE ELEMENTS							
ALIPHATICS, ALICYCLICS							
AND FATTY ACIDS		1		1			
Acetic Acid	3.3	4.7E+1	7.0E-2			5.0E-1	6.6
Butanoie Acid	3.1E-1	6.1E+1	5.1E-3	2.0E+1	1.6E-2		
Hexanoic Acid	2.4E-2	2.2E+1	1.1E-3	1.0E-2	2.4	4.4	5.5E-3
3-Methylbutanoic Acid	2.4E-2	Ĺ					
2-Methylpropanoic Acid	4.82-2			3.5E+2	5.5E-4		
Pentanoic Acid	2.8E-1	7.7E+1	3.6E-3			3.9	7.3E-2
Propanoic Acid	6.3E-1	5.0E+1	1.3E-2		· · · ·		£
TOTAL FATTY ACIDS			•	I	·		•
BENZENES & SUBSTITUTED		1			·		
BENZENES	l		· ·		ľ		
Biphenvl	1.6E-1	<u> </u>	ļ	<u> </u>			
<u>Echylbenzene</u>	7.3E-1	3.2E+1	2.3E-2	ļ		2-5E-1	2.9
Indan	2.0	ļ		<u> </u>	<u> </u>	4.0E-1	2.9
Toluene	2.4	9.5	2.5E-1	3.1	7.72-1	2.5E=1	9.6
1,2,4-Trimethylbenzene	ļ	<u> </u>	<u> </u>	1			
o-Xvlene	8.3E-1			5.0	1.7E-1	5.0E-1	1.7

TABLE 2-4 (continued)

	A Estimated	B Lowest	A/B	C Lovest	۸/c .	D EPC C	A/:D
	Post- Dilution Conc. mg/l	Observed LC ^a 50 mg/1		Observed Toxic ^b Conc. mg/l	•	лg/1	
PHENOLS						·	
Catechol	4.4	1.4E+1	3.1E-1	3.0	1.5	1.0E-1	4.4E+1
3,6-Dimethylcatechol	3.6E-1	·					
3-Methylcatechol							
4-Methvlcatechol	3.1			7.0E+1.	\$.4E-2		
2-Methylphenol	3.3E-2	5.0	6.6E-3	2.0	1.7E-2	5.05-2 ^d	5.5E-1
J-Hethylphenol	4.8E-2	1.9E+1	2.52-3	7.0	6.9E-1	5.0E-24	9.52-1
4-Methylphenol	3.0E-2	1.4	2.1E-2			3.0E-2d	6.0E-1
4-Methylresorcinol	2.8E-1						
5-Methvlresorcinol	5.3E-1	l					
Phenol	9.6E-Z	1.4	5.9E-2	1.0E-2	9.6	5.0E-1	1.9E-2
Resorcinol	1.5	8.0E-1	1.9			1.0E-1	1.5E+1
2.4-Xylenol	9.1E-2	1.3E+1	7.0E-3			1.0e	9.1E-7
3,5-Xylenol	1.3E-1	5.0E+1	2.6E-3	1.6E+1	9.1E-3	1.0°	1.3E-1
TOTAL PHENOLS	10.3			· ·		1.0E-1	1.0E+2
POLYNUCLEAR AROMATIC HYDROCARBONS			•			· ·	
Acenaphthalene ·	3.0E-2	•					
Anthracene	7.6E-3	//		5.0 /	1.5E-3		
Benz(a)anthracene	7.6E-4			1.0 🖔	7.62-4		
Benzo(g,h,i)pervlene	2.2E-5				` :		
Benzo(a)pyrene	3.0E-4						
Benzo(e)pyrene	3.0E-4		1				
Chrysene	1.5E-4		1	5.0	3.0E-5	·	
Fluoranthene	1.5E-2	1	Ì	1.0E-1	1.5E-1		
Fluorene	1.5E-2			5.0	3.0E-3		
Naphthalene	7.1E-1	2.4 .	3.0E-1	1.0E-2	7.0E+1	5.0E~2	1.4E+1
Pervlene	1.2E-4	3.05-5	1	1.0	3.0E-5		
Phenanthrene	7.6E~3	1.1	6.9E-3	1.42-3	5.4E-1	·	
Pyrene	1.5E-2	1		1.0E+1	1.5E-3		
TOTAL PAH's							
SULFUR HETEROCYCLICS		<u>}</u> _					
Methylthiophene		<u> </u>		^ 		ļ	
Thiophene	ļ	Ļ	 	ļ			
TOTAL THIOPHENES		1		L <u>'</u>	l		

.

. .

TABLE 2-4 (concluded)

	A	B	A/B	l c	A/C	(D	1 4/12
	Estimated Post- Dilution Conc. mg/1	Lowest Observed LC ₅₀ a mg/1	,	Lowest Observed Toxic ⁰ Conc.	., .		
NITROGEN HETEROCYCLICS		·····		1 mg/1		11g/ 1	┝━╍╼╍╼╸╿
2,4-Dimechvlpyridina	6.6E-4		•		:		
2,5-Dimethylpyridine	6.6E-4						
2-Methylpyridine	4.6E-2						
3-Methylpyridine	1.7E-1						
4-Methylpyridine	4.1E-1						
Pyridine	7.5E-3	6.3E+2	1.2E-5	1.5E+1	5.0E-4	5.0	1.5E-3
Quinoline	6.3E-3	1.0E+1	6.3E-4	3.8	1.7E-3	5.0E-1	1.3E-2
OXYGEN HETEROCYCLICS Benzofuran	۰.						
Dibenzofuran	5.6E-3					·	
MERCAPTANS Methanethiol	1.5			5.0E-1	3.0		
TOTAL MERCAPTANS	<u></u>			6			<u>`</u>
AROMATIC AMINES Aniline TOTAL AROMATIC AMINES	<u>].3E-3</u>	4.0E-1	<u>8.3E-3</u>			5.0E-1	6.6E-3
NITROSAMINES							
MISCELLANEOUS Amnonia		r				Ĭ	. /
Carbonyl Sulfide							,
Hydrogen Cyanide							
Hvdrogen Sulfide		•				<u> </u>	
Nickel Carbonyl					,		
x			<u>:</u>		··	·	
Particulates						<u> </u>	
30 _x						; 	
Tars, Oils, Naphtha						l	

^aValues are for <u>Daphnia</u> <u>sp</u>. or fish, 24-96 hr/References for individual compounds are given in Ecological Report.

...

^bRegardless of species, endpoint or exposure conditions ⁴⁹.

^CEstimated Permissible Concentrations for water and ecology^{34,35}.

dvalue is for total cresols

eValue is for total xylenols

.

and organic contaminants most likely to occur in this waste stream, their expected concentrations following dilution in the receiving stream, and compare these concentrations with EPA's estimated permissible concentrations, mean toxic concentrations, and other indicators of potential hazards.

From these tables it is evident that Stream 53 presents a potentially greater hazard to receiving systems than the ash leachate (Stream 69), because of both relatively greater trace element concentrations, and the presence of numerous organics at relatively high concentrations in the former. Of the several trace elements listed in Table 2-3, only vanadium falls significantly below every "indicator" or criterion concentration "ambient" shown (except freshwater concentrations). Cadmium and mercury appear to represent the most hazardous trace elements in the stream, exceeding lowest observed toxic concentrations by a factor of several hundred. Again, as with the indices of ecological hazard developed for the ash leachate constituents, these results often are based on sparse data and, accordingly, must be interpreted with caution. All of the other qualifications placed on the assessment of the ash leachate also apply equally to the reverse osmosis waste stream. The results do suggest, however, that certain contaminants are more likely than others to occur in this waste stream at concentrations harmful to aquatic environments.

Even fewer data are available on the toxicity and bioaccumulation potential of organic contaminants likely to occur in the concentrated waste stream. At least one published toxic concentration was found for 31 of the 49 organic compounds listed in Table 2-4 as probable contaminants in the concentrated waste solution. Of these 31 organic compounds, only resorcinol was found, by a factor of 2, to exceed the lowest observed LC_{50} concentration. With respect to the lowest observed toxic concentrations regardless of endpoint (death, behavior shifts, reproductive inhibition, etc.), target species, or exposure conditions, several organic constituents, including resorcinol, naphthalene; phenol, methanethiol, hexanoic acid, and catechol were projected to occur at

٠.

levels potentially hazardous to aquatic organisms. Acetic acid, catechol, resorcinol, ethylbenzene, indan, naphthalene, toluene, and oxyleneⁿ exceeded EPA's estimated permissible concentrations for freshwater systems^{10,11}.

Photolysis, adsorption to sediments and suspended solids, and microbial degradation are important mechanisms for removal of many of the organics, including the lower-molecular-weight, 2- and 3-ring PAH's such as acenaphrhylene, fluorene, naphthalene, anthracene, fluoranrhene, and phenanthrene.²⁴ Bioaccumulation of these compounds by higher organisms is rapid, but so is their metabolism. Much the same can be said for the 4-ring PAH's such as benzo(a)anthracene, chrysene, and pyrene; biodegradation, though important, will probably occur at a slower rate than for the 2- and 3-ring compounds.7 Photolysis and adsorption onto sediments are also very important processes for the removal from the water column of higher-molecular-weight compounds such as benzo(a)pyrene and benzo(g,h,i)perylene. Microbial degradation is the final fate of these compounds, but the process may take longer (months or 🛛 years) than for lower-molecular-weight compounds.²⁴ Bioaccumulation is rapid, and equilibrium body burdens increase rapidly with molecular weight.²⁴ A microcosm study of the bioaccumulation of benzo(a)pyrene yielded the following concentration factors (ratio of concentration in an organism to concentration in water):⁷ fish, 930; algae, 5,300; mosquitos, 12,000; snails, 82,000; and Daphnia sp., 134,000. Transport, transformation, and fate of many of these organic contaminants⁷ as well as trace elements are summarized in the Appendix to this volume.

1

The total organic content of this stream after dilution (24 mg/l) also represents a hazard for aquatic life because oxygen may be lowered below the minimum requirements of many aquatic organisms. Furthermore, many contaminants may become far more toxic at low levels of dissolved oxygen.

The principal utility in presenting these lowest published toxic concentrations is not in their value as indicators of maximum absolute relative toxicity among the several potential toxicity or even contaminants. One compound may appear far more toxic than another simply because the former has been more often the subject of investigation than the latter, or one compound has been tested for sublethal concentrations more than the latter, or one compound has been tested for sublethal effects on an unusually sensitive "organism while testing of another has been limited to 96-hr LC50's for more robust laboratory animals. Exposure conditions and endpoints vary widely, while a few reported toxicities may be in error or reflect the presence of confounding factors. The major value of presenting these lowest toxic concentrations, then, is to suggest the magnitude of uncertainty and, therefore, caution that must accompany the use of published LC50's, EPC's, or other indices to assess the actual or relative potential hazard of contaminants in a given stream, Thus, for example, phenol (after dilution in the receiving stream) is expected to occur at less than 7% of the lowest observed 48-hr, LC_{50} concentration for trout⁴², but at nearly 100 times the concentration reported to inhibit growth of certain green algae.³⁶ Further, a separate study¹⁹ reported 20% inhibition of a green alga, Selenastrum sp., by a phenol concentration of 174 mg/1, which is 17,400 times greater than the former algal study's test concentration.

Aside from the unanswered questions of interaction (whole effluent toxicity), carcinogenicity, and toxicity of untested and/or unknown constituents, the few data presently available indicate that Stream 53, the concentrated waste solution from the reverse osmosis unit, is likely to exhibit high concentrations of several toxic trace elements and organic compounds. Among those contaminants for which data exist, cadmium, mercury, catechol, resorcinol, and uaphthalene may occur at especially high levels. Leakage or discharge of this effluent represents a significant threat to aquatic ecosystems and therefore calls for carefully designed and constructed disposal facilities to ensure its isolation from the environment. Based on its rate of flow and predicted concentrations for the known contaminants, this effluent would appear to have concentrations more hazardous to aquatic ecosystems than either ash leachate or biosludge leachate. Final judgment on the relative risks posed by Stream 53 must await thorough characterization of actual, whole effluents from appropriate operating plants as to composition, acute and chronic toxicity, and carcinogenicity to sensitive aquatic organisms, and finally ecosystems - level effects using microcosms or small "sections" of real ecosystems.⁴⁰

2.3 BIOSLUDGE (Stream 70)

Volume II, Section 2.4 describes the biological sludge generated by the wastewater biotreatment unit in terms of its more environmentally important constituents, their rates of production, and the methods and assumptions used in estimating them. Because the question of biosludge disposal has yet to be resolved, and the mobility of the various contaminants in the sludge is unknown, an assessment of the hazards posed to aquatic ecosystems is difficult. If the sludge is gasified with the feed coal many of the potential hazards will be removed. Unfortunately, this partial solution has not yet been demonstrated for indirect liquefaction. This study therefore assumes the sludge is to be stored in or on the ground, such as at a landfill, and that all of the contaminants listed in Table 2-5 are ultimately released into a 283 1/s (10 cfs) freshwater receiving stream. The assumption of complete mobility is probably too conservative, but is assumed because of a lack of data on this point.

Concentrations of several contaminants after dilution in a 283 1/s (10 cfs) receiving stream are compared with various criteria in Table 2-5. Criteria include estimated permissible concentrations, lowest observed lethal concentrations, lowest observed toxicity regardless of endpoint (mostly sublethal), mean toxic concentration for crustaceans, chronic toxicity concentrations for <u>Daphnia magna</u>, threshold bioaccumulation concentrations, proposed freshwater criteria TABLE 2-5

.'

÷.; BIOSLUDCE (STREAM 70): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL, CONCENTRATIONS WITH ECOLOGICAL BENCHMARKS

	<	-	VIII I		A/1:	-	A/1.		A 15 1	4	15					•	
		1		•	;	 -		• •	1	•	2	 ; []		3	11/1	-	1/1
	נזור.			laucs1		Jourst		Nean		Chronic			-	Proposed		Ambient	
-	Pillut ion			Ubserved EC b	<u> </u>	Upserved Toxic		Toxic		Toxir.			- 	Criteria		Ft esh-	
	Lonc. ug/2			-05		Conc.		1/ 3hu		mg./2		Conc.		rresh- water ⁸		Conc.	
THACE LLIMENTS																	İ
Aluminum									 				_	_			
Arstenic	2.4E-1	1.06-2	2.46-2	2.21-2	1.1E11	2.2E-2	1.1611	3.1	7.7E-2	5.28-3	4-61-1	1-10.5	4.8E1	5.76-2	4.2	3.55-3	1136:)
Bervllium	1-36-1	1.1E-2.	1.2E11.	1-12.1	8.72-1	T-35-T	1=17.8.	2.8	1.3E=2			ירוזר.נ	C-36-7	.17 <i>E-</i> á	2136.1	ζ=30. Γ.	2136.1.
Boi on	 																
	7.1E-2	4.016-4	1.8E42	9.01-4	7:9E11	1.71-4	4.2612	3.5E-2	2.0	1.76-4	4.2EH2	2.01:-3	1.6611	J. BE-4	1.9612	2.4F-4	3.0E12
Copper																; ;	
Fluor inc.							:									1	
11.011																	
	8.91-2	1-30.1	8.9	3.46-1	2.6E-2	3.01-2	3.0	1.8	4.9E-2	3.0E-2	3.0	6.01-3	1.5141	1.36-2	6.8	4.45-3	2.0611
	1	 	İ	1 1 1 1	·												
Hercury	2.16-2	5.0E-5	4.2E12	5.0E-3	4.2	4.00-5	5. 1E12	9.0E-3	2.3	3.46-3	6.2	7.01:5	3.08+24	6.48-5 ¹	3.3612	2-30-2	3.0112
Nickel															;	:	
Selenim								. -				1			•	:	
Vanad jun												· 、	:		- : 	:	
ZInc								ĺ	1						• • •	:	•
TOTAL. TRACE ELEPTINES															1		
ALTHIATICS, ALTCOLLCS					-										·	 . '	
AND FATTY ACTOS					- 11											<u> </u>	
Acet is Auld	i			1		1							 ! !		i		• :
- Buranois Acid	ļ	:		, 1 1								 	! 	 	:		
liexanoje. Ac lu												 : ;					
3 Methythutanole Acid					:		i							1			
.2-Nuthylpinpanoic Acid .	: :	;	-	:			:						- 1	:		;	
Pentanoic Arid	••••••••••••••••••••••••••••••••••••••					•;		: :		i	;	!	;	:	:		j
Preparate Acid	·,		:	.'		 : :				1		י ; ו	:				·
i jorai, Fairy actus		:	 ;			 ! :						ļ			!		
N.N.ZYMES & SHART LTGTED			, , ,		: :	•	: : :	:	 	 		 !	i		*	:	! :
			:												•		
		;		:		• • •	1	•			·····		- ;		:	•	
. Indan				- 1	•	 ,					·		· · ·		:	:	
. Tolucie		terre el .		:			•	:					 - -	:		۰.	
1,2,6 Telas the the thrown		•••••		•					•			<u></u>	:				
o Xybrue									 !								л [;]
						.*								:			

۰ ،

			١.			Table	25	(cont i	(nued)								
	<	-	A/B	U	V/C	a	4/N	21	A/E	عظ	A/F	0	A/G	=	11/V		1/1
	Eut.			I.ovest		Lover		Hran		Chronic		Three- hold		patrodo I,	;	arb fear	
	Huclan Conc.			1.c ₅₀ b		Tuxle Cone.		Conc.		Conc.	:	nlo- accub.		Fresh-		vater Later	
	mg/t	i				1/11		-				Cont.		1 /3/			
Catechul									14. 14.		۱			•			1
J. 6-Dimethyleatechol		ļ		•			ļ								 :		ļ
J -Nethylcalechol																:	
4-Rethylratechol									-	•						:	
2-Hethylphenal																	
] Altering I placed							÷								ľ	;	
4-Het hy I phenol																	ĺ
4-Mithylresorcinol				·													
- S-Hethylresorchiol -			Ì								•						
Physical	İ											.5				 - - -	
Hespicinel												1					
2.4-Xv1enul								:				. //					· ;
												~ <u>.</u>	7			:	
TOTAL PULLIOLS																	
POLYNNELLAR AKOUATIC	 											; 	1		1	:	
Acessighthal ene	215-1																20
	6.7E-2					5.0	1.35-2						•				
Benz(a) anthracene	6.2E-3.	:		İ		1.0	<u>6.7E-2</u>										
	2.05-4	•		Ì		İ				'		ļ		.		; ;	
	2.25-3-			-					 								. !
Bruzu(e) hy cene	2.215-3				•	Ì						 					. !
Chrystene	1.35-3.				ĺ			ĺ		.						 - - - -	
Flipt and home	1.48-1					1.06-1	1.4							2.5E-1	2.66-1	ل :	,
I hup date	1.48-1		;	i		5.0	2.8E-2						 			 - - -	
headed had success	1.7	5.06-2	3.4611	2.4	7.11-1	1.06-2	1.71:12								 	:	1
. Purylith:				1									 				
. Phenanthrene	6.78-2			1.1	6.1E-2	1.45-2	4.8										
	L. 3E=1					1,0E1T.	1.3E-2.						1				
TOTAL PAR'S																	
Survive, inclusion you and															 i	 !	
Rethy Hildplug	.i	1					•						<u>.</u>			:	:
jhtophene .	:	:	:	:							i j		:	:			;
		<u>ا</u> نـــ				- 	1	Ì	÷	 	-	- :			1 		-
			•	•													

.

23

.

÷

ı

3

:

(continued	
2 - 5	:
TABLE	

1/1			•									 :	 !											!	; ; ; ~	ł	•	 		1	İ	•
-	Amb Lent Freeh-	ualer h	1/1m		·		~				:		1	1		;;;				: ! .		;		:	:				1 1 1	· · ;	:	<u>;</u>
A/II			,		İ							: 1 1				 			:						1		:		. 1			 :
=	Propose	Frush-	ng/1																					!	;;	:		!		i	, ,	:
A/G									.				:			•]								:	;	 :		:	•	:	:
	Thres- hold	Blo-	Conc.							İ	!					i	1								:		:			; ;	:	 ; ;
A/F																1																
*	Chronic Toxic	Conc.	2 / V	, , , , , , , , , , , , , , , , , , ,	·														İ						İ			 				i
<u>л/б. 1</u>		-											i			;			 					1	;			:	;			 - :
н.	Mean	Conc. e	1												-									İ		i i !	į				!	 i :
u/v							ļ	:			1													1						i		 ,
=	Lovest	TuxIc	III:/I	i -	 								1		· .		, ! ! 							;				;			:	
V/C			•								:				•			<u>.</u>			<i></i>			:		:						
ບ	122403	1.c ₅₀ b	1/Su			• [•									;	:		:	•		ļ	
N/B		<u> </u>					' 																					 ! !		 1		
=	EPC ⁴					 			 i j		i						 i				<u>-</u>	<u>.</u>	•				!			:	:	
۷	Est.	lint fan	mg/f							 								•					<u> </u>			 						
-		<u>-</u> <u></u>		UTTROCEN HEVERVICYCLICS	2,4-Damethylpyrjdlne	2, 5-Dimethylnyr Idine	2-Methylpyr Idine	3-Methylpvridine	4-Mai hy) pyr 1d i ne	Pyridine	Outnutine	XYGEN HETEROCYCLACS	Benzofuran	Dihenzofuran	ILIN'APTANS	Methanethol	TOTAL HERCAPTANS	UCHATIC MURES	Anf] ine		NI TROSAN NES		ALSCRI, ANGUS		_ Garbeny) Sulfide	. Ilydrogen Cyanide	lydroeen sulfide	Mirkel Carlony]	NO _X	. Pari iculates	su _x	lars, Oljs, Kyhnha

.

TABLE 2=5 (concluded)

^aEstimated Permissible Concentrations for Freshwater Ecosystems³⁵.

· · · · ^cIncludes "No Effect" concentrations⁴⁹, 114, 132, 139, 173 ^bExposures of 24-96 hours⁴⁹, 141, 173.

nî P

d_{Values} are for crustaceans except for beryllium which represents fish toxicity data.

^eValues are for <u>Daphnla magna</u>¹².

fReference 89.

 $^{
m g}$ Assumes hardness = 50 mg/l as CaC0 $_{
m 3}$

hReference 106.

ⁱInorganic mercury.

and ambient freshwater concentrations. These data are unavailable for most of the organic contaminants expected to occur in the sludge.

It is evident from the table that all five trace elements listed would exceed at least two of the criteria, ambient freshwater concentrations and the EPC_{we} 's, if the elements were completely mobilized from the sludge into the receiving stream. Cadmium and mercury appear to present the greatest hazards to an aquatic ecosystem, followed by arsenic and lead. Beryllium concentrations initially approach lowest observed toxic concentrations, but this element's relative insolubility and apparent propensities for adsorbing to particulates or hydrolyzing to form insoluble compounds⁷ would probably result in concentrations far below hazardous levels.

Of those few PAH's for which toxicity data exist, naphthalene appears to be most acutely toxic in sludge leachates, due primarily to its high concentration, followed by phenanthrene and fluoranthene. Pyrene, fluorene, anthracene, and benzo(a)anthracene occur well below observed acute toxic concentrations. With the exception of acenaphthylene (270 μ g/1), the other PAH's would occur in the receiving stream in concentrations less than 3 $\mu g/l.$ Although the latter compounds are unlikely to be acute at these concentrations, the questions of chronic toxicity, toxic interactions, carcinogenicity and mutagenicity remain. Benzo(a)pyrene, fluoranthene, and phenanthrene are among the active carcinogens³⁶ expected to occur in the biosludge. In the presence of certain other organics, the carcinogenicity of PAH's may increase by several orders of magnitude.²⁴ Information concerning PAH photolysis, adsorption, metabolism, bioaccumulation and degradation has been discussed previously in Section 2.2.

On the basis of this information, cadmium, mercury, and naphthalene in biosludge appear to pose the greatest hazard to aquatic ecosystems. Total organics may cause oxygen depletion, which in turn increases the toxicity of many substances. However, the limited data presented here are overwhelmed by the uncertainties regarding the other

compounds, leachability, interactions among components, and method of sludge disposal. Transport, transformation and fate of many of these substances are summarized in the Appendix to this volume.

In conclusion, the biosludge should be considered a hazardous waste requiring either gasification or effective containment in welldesigned and operated disposal facilities, until whole biosludge leachates from operating indirect coal liquefaction plants can be adequately characterized as to composition, leachability, acute and chronic toxicity to sensitive aquatic organisms, and carcinogenicity.

3 GASEOUS EMISSIONS

- - - -

3.1 UTILITY STACK GAS (Stream 28)

c

The utility stack emissions comprise a major source of air pollutants. Among the most important are particulates, the toxic gases SO_x , and NO_x and the trace metals As, Be, Cd, Pb, and Hg. Many of the metals will condense on the surface of the particulates or form an integral part of particulate structure. B, Ba, Co, Cr, Cu, F, Mn, Se, Sn, U, V, Zn, and other trace elements are also likely to occur in the stack gases. Existing information is inadequate for quantifying emission rates of these elements.

Table 3-1 presents estimated emission rates, post-dilution concentration in air, and the relationship of air concentrations to various standards, criteria, and toxicities for each of the listed pollutants. The post-dilution concentrations in air are based on a dilution factor of 235 which was derived from EPA's Source Analysis Model 1 (SAM/1) for the dispersion of atmospheric emissions.⁵⁶ This model incorporates a Gaussian plume dispersion model and wind speeds, atmospheric stability, and stack heights characteristic of average national conditions to predict the maximum concentrations. The actual concentrations might differ radically from those given in Table 3-1.

Standards and criteria for ecological protection from many air pollutants are often lacking. Table 3-1 presents the most stringent criteria, lowest observed toxic concentrations, ecological Estimated Permissible Concentrations, and ambient air concentrations or indicators of relative hazard. The scarcity of data required the use of the lowest published toxic concentrations regardless of species, endpoints, and exposure conditions.

Occurring at an estimated concentration approaching 9 times the national secondary ambient air quality standard²¹, SO_x is deserving of special consideration as a potential hazard. SO_x also exceeds the lowest observed concentration causing chronic toxicity symptoms in
TABLE 3-1

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

	٨		A./ D	-	- A/2			l	
	A Estimated Post- Dilution Conc (Hg/m ³) ^a	B Most Stringent Criteria (ug/m ³) ^b	A/ D	Lowest Observed Toxic Conc. (ug/m ³) ^C	, alc	υ ΕΡΟ Ε (μς/π ³) ^d	A/D	E Ambient Air Conc. (ug/m ³) ^e	A/E
TRACE ELEMENTS									
Aluminum									
Arsenic	5.8E-4	2	2.9E-4	<u> </u>		5.0E-3	1.22-1	1.5E-2	3.9E-2
Beryllium	6.1E-4	2	3.1E-4	3.58+1	1.7E-5	5.0E-3	1.2E-1	2.0E-4	3.1
Boron									
Cadmisme	5.1E-4	4.0E+1	1.3E-5	1.0E+1	5.1E-5	<u>1.2E-1</u>	4.3E-3	1.02-3	5.1E-1
Copper									
Fluorine									
Iron	· · · ·								
Lead	6.0E-3	1.5	4.0E-3			3.6E-1	1.1E-1	2.2E-2	.2:7E-1
Manganese									
Mercury	3.9E-2	5.0E+1	7.8E-4	1.0E+1	3.9E-3	1.0E-1	4.0E-1	7.0E-5	5.6E+2
Nickel									
Selenium		نتريب		•			•		
Vanadium				÷					
2Inc									
TOTAL TRACE ELEMENTS					•				
ALIPHATICS; ALICYCLICS AND FATTY ACIDS									
Acetic Acid									÷
Bucanoic Acid		ſ							ţ,
Hexanoic Acid									
3-Methylbutanoic Acid									
2-Methylpropanoic Acid									
Pentanoic Acid					-				
Propanoic Acid	· · · ·								
TOTAL FATTY ACIDS							١٠		
BENZENES & SUBSTITUTED BENZENES	**								
Biphenvl	•								
Echylbenzene	<u> </u>	<u> </u>				-			
Indan		<u> </u>	-						
Toluene	ļ								
1,2,4-Trimethylbenzene									
o-Xylene	<u> </u>								

.

.

.

.

TABLE	3-1	(continued)
-------	-----	-------------

<u>э</u>			-,						
	A Estimated Post- Dilution Conc. (µg/m ³) ^a	B Nost Stringent Criteria, (ug/m ⁻⁾ b	A/B	C Lowest Observed Toxic Conc3 (ug/m ³) ^C	A/C =	D EFC _E (ug/m ³) ^d	A/D	E Ambient Air Conç. (ug/m)	A/E '
PHENOLS									
Catechol									
3,6-Dimethylcatechol	·	ŀ						· · · · ·	
3-Methylcatechol				<u> </u>					_ :
4-Methvlcatechol									
2-Methylphenol	·								
3-Methylphenol									
4-Methylphenol		÷.							
4-Methylresorcinol		· · · ·							
5-Methylresorcinol									
Phenol							•		
Resorcinol		;.							
2,4-Xylenol		\. \.	``	•					•
3,5-Xylenol		ì		•					
TOTAL PHENOLS				`	•				
POLYNUCLEAR AROMATIC HYDRGCARBONS									
Acenaphicnalene									
Anthracene				· · · · · · · · · · · · · · · · · · ·		 			
Benz(a)anthracene									
Benzo(g,h,i)perviene									41
Benzo(a) pyrene		,						·	
Benzo(e)pyrene	<u> </u>	· <u> </u>							
Chrysene							· ·	· ·	
Fluoranthene		<u> </u>				l I			
Fluorene						ļ	l		
Naphthalene									•••••••
Pervlene		<u> </u>		ļ			<u> </u>		
Phenanthrene		ļ			·	<u> ' </u>			
Pyrene		<u> </u>							
TOTAL PAH's	<u> </u>			<u> </u>		L			
SULFUR HETEROCYCLICS Hethvlthiophene				•					
Thiophene	<u> </u>								
TOTAL THIOPHENES									

TABLE 3-1 (Continued)

•	٨	В	A/B	C.	A/C	G	A/D	E	A/E
	Estimated Post- Dilution Conc ₃ (Ho/m ³) ^a	Most Stringent Criteria (µg/m ³) ^D	4.	Lowest Observed Toxic Conc. (42/mJ) ^c	: ´	EPC E (µg/m3) ^d		Ambient Air Conc. (µg/m ³) ^e	
NITROGEN HETEROCYCLICS									
2,4-Dimethylpvridine							· ·		
2,5-Dimethylpyridine									
2-Methylpyridine					·				
3-Methylpyridine									
4-Methylpyridine						ł			
Pyridine			· ·	· ·				·	
Quinoline				·					
OXYGEN HETEROCYCLICS				`.				1	
Benzofuran					· ·		_		
Dibenzofuran									
MERCAPTANS								[i .
Hethanethiol				i					
TOTAL MERCAPTANS	*					•		L	
AROMATIC AMINES									
Aniline									
TOTAL AROMATIC AMINES				•		1			
NITROSAMINES	<u> </u>					İ			
	<u></u>								
MISCELLANEOUS									
Amonia						L			
Carbonyl Sulfide	ļ								
Hvdrogen Cyanide									
Hydrogen Sulfide	<u> </u>								
Nickel Carbonyl	<u>ļ</u>	1.5E+2				1.0E-1		9.0E-2	
NO _x	1.3E+2	1.0E+2	1.3	4.4E+2	3.0E-1				
Particulates	2.0	60	3.3E-2			l			
. \$0 _x	7.0E+2	8.0E+1	8.8	8.6E+1	8.1	ŀ			
Tars, Oils, Nachtha						:			_

...31

э

I

..

¢

TABLE 3-1 (Concluded)

 ^aBased on dilution factors derived from SAM/1 model no data were available for many other pollutants_likely to be present such as selenium, boron, fluorine, manganese or vanadium
 ^bNational Primary and Secondary Ambient Air Quality Standards <u>OR</u> NIOSH⁸⁰
 ^cLowest toxic concentrations regardless of species, response, exposure conditions³⁵
 ^dEstimated permissible concentrations in air for ecology³⁵

e_{Median} concentrations for USA¹⁷, 190

vegetation⁴⁶ by a factor of 8. The estimated concentration of NO_x after dilution exceeds the national standard by a factor of 1.3.

 SO_x , as SO_2 , is generally more toxic to plants than to animals. Direct effects include passage through the leaf stomata where it combines with water to form sulfite salts and sulfurous acid.¹⁷ At high enough concentrations, these substances will destroy chlorophyll and eventually the entire leaf. At sufficiently high concentrations, both SO_x and NO_x can produce serious indirect effects on ecosystems of entire regions through the formation of acid precipitation¹⁰ (sulfuric, nitrous, and nitric acids). SO_x and NO_x are also known to interact synergistically.¹⁷

The estimated post-dilution concentrations of N1, Be, and Hg exceed ambient air concentrations (U.S.A.) by factors of 5.9, 3.1 and 560, rejectively.

Table 3-2 presents the results of an attempt to estimate soil deposition flux of several trace elements from stack gas emission rates. Using the relationship between emission rates and maximum deposition flux generated by Vaughan⁵⁴ for a site near St. Louis, the deposition rates to be expected from a hypothetical liquefaction plant with a 300-m stack were calculated. As shown in Table 3-2, with the exception of Hg, the annual maximum deposition of each metal from the hypothetical plant represents a small percentage of the total natural flux from rock weathering, rain, and dust fallout of that metal to an "average" uncontaminated and uncultivated soil. Even if 100% rather than 6% deposition of trace elements within 50 km of the site is assumed, project-related deposition of the metals is a relatively small fraction of natural metal flux, again with Hg a striking exception (worst-case).

A study of an actual coal-burning power plant found soils near the plant to contain several hundred times as much Hg as background soils.²⁷ Globally, the combustion of fossil fuels has been shown to contribute a significant fraction of the total Hg mobilized each

(UTILITY STACK CASES): INPACTS OF TRACE ELEMENTS ON SOILS. STREAN 28 TABLE 3-2

	v	=	0	a	- 	3	;;	=		-	×	-	×
ELLERINTS	Failssion Rate ^a my/6	Max Imm Nepos I F J cm P Lox b J R J m ² / y r	Hax faum Deposition After After After After	Change In Annual Solt Conc. ^c Hg/g	Horet- Caue Max Ruun Ruxd Fluxd Pg/m ² 7yr	Horat- Case Histaum Heposffin After After After Hg/m ²	Harst- Case Chunge in Aunual Sofi , Conc.d , RR/B	Natural Flux to Sylle µg/m ² /yr	Mean Sol I Gonc , f J48/8		ے بنانی	 2:1	י. -יפ
Агненде	<u>8.66-2</u>	<u>1.8Ľ-2</u>	7.2E-1	+7.58-7	<u> 36-1</u>	1.28+1	11.36-5	1.46	6E D	1.35-4	2.18 ² 0	1. JE-7	2, 2E-6
Berylliun	1-06-1	2.2E-2	0.6E-1	19.21-7	3.76-1	L.4E) L	41.5E-5		68.0			1.5E-7	2.68-6
	8-81-2	1.05-2	7.25-1	+7.58-7	<u>JE-1</u>	1.2511	41.3E-5	1.66/1	6E-2	1.1E-3	1.98-2	1.3 <u>K-5</u>	2, 2E-4
J. ad	1.01:0	2.15-1	8.48 0	49.08-6	3.5F.0	1.48+2	41.56-4	4.7842	1-061-1	4.5E-4	7.46-3	98-7	1.5E-5
Mercury	6.36.0	1. 3E 0	5.26+3	+55E-5	2.2E11	8.7E12	19.2E-4	1.3E 0	38-2	1.9E 0	1.7E11.	1.06-3	J. IE-2
Nickel	<u>B.9E+1.</u>	2.38.1	9.164.2	49.5E-4	3.8512	1.58+4-	11.6E-2	2.5Eb4	4.011	9.2E-3	1.5E-1	. 2.4E-5	45-4

^a Based on stream characterization data for conceptual reference [aclity (See Volume 11)

b Bestimated by using Battelle study model which calculates trace element transport and deposition from 300-m 213 stack of hypothetical 1400-MMe plant sited near St. Louis, assuming 6% deposition within 50 km of plant

cAnnual increase in soll concentration from conceptual coal conversion deposition assuming no soil output; ^eAnnual input to uncontaminated, uncultivated soil from rock weathering, rain, and dust. assumes soil density = 1.2 g/cm³, retention of trace elements in top 2 cm of soil. ^dAs (a) above, but assumes 100% rather than 6% deposition within 50 km of plant. Mean endogenous soil concentration.²¹³

 $^{
m h}$ katio of worst-case annual project related deposition to natural annual flux to soil. $^{
m 17}$ ^Bkatio.of maximum amnual project-related deposition to natural amnual flux to soil.¹⁷

¹Ratio of annual project-induced soil concentration increase to mean endogenous soil concentration.²¹³

י<u>ן</u> ...: 213 ^JRatio of annual worst-case project-induced soil concentration increase to mean endogenous soil concentration.

Ľ

5

year.^{33,44} In view of the considerable toxicity of Hg compounds^{23,32,44} as well as the potential magnitude of releases estimated for indirect coal liquefaction, Hg emissions should be considered a potential ecological threat deserving the highest research priority.

:.

3.2 EVAPORATIVE EMISSIONS AND COOLING TOWERS DRIFT (Stream 29)

Table 3-3 shows the estimated rates of emission for several individual contaminants expected to occur in the cooling-tower evaporation losses and/or drift. As with the other waste streams addressed in this study, many other trace elements and compounds, some potentially harmful, may be released via this stream, but existing information is insufficient for even a rough estimate of emission rates. Another important assumption is that contaminant concentration in the makeup water is zero. In actual practice, many of the contaminants, particularly the trace elements, and total dissolved solids (TDS), would be present in the make-up water and consequently would undergo several cycles of concentration depending on the quality and availability of water at the site. In some cases, the cooling tower emission rates of certain contaminants and TDS listed in Table 3-3 would be increased significantly.

Prediction of post-dilution contaminant concentrations in air using the SAM/1 dispersion model is inappropriate because the emissions are biphasic. Also the partitioning of each contaminant between the two stream phases (vapor and drift) is unknown, although many trace elements and PAH's, on the basis of such physical characteristics as solubilities or vapor pressure, might be expected to dominate in the drift, while phenols and low-molecule-weight, heterocyclic, nitrogen-substituted compounds (pyridines) may favor the vapor phase.

Partitioning of contaminants between the two phases is important because the drift (droplet) phase will settle to the ground over a much more limited area, relatively closer to the plant than the vapor phase. Thus, whatever contaminants are present in the drift phase (e.g., TDS, PAH's, and certain trace elements) will tend to become

35 、

٤.

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

.

÷

-			4.
Compound/Trace Elements	Emission Rate mg/s	Compound/Trace Elements	Emission Rate mg/s
Arsenic	5.5	3,5-Xylenol	2.8
Beryllium	2.6	3,6-Dimethyl catechol	24
Cadmium	3.0	4-Methyl resorcinol	19
Fluorine	120	4-Methylcatechol	200
Lead	5.8	4-Merhylphenol	2.0
Mercury	0.46	4-Methylpyridine	0.27
Nickel	0.15	5-Methylresorcinol	33
Vanadium	0.046	Acenaphthylene	0.061
Ammonia	7,600 .	Anthracene	0.015
Acetic acid	. 640	Benz(a)anthracene	0.0015
Aniline	. 0.40	Benz(a)pyrenė	6.1×10^{-4}
Butanoic acid	36	Benzo(e)pyrene	6.1×10^{-4}
Catechol .	290	Benzo(g,h,i)perylene	6.1x10 ⁻⁵
Hexanoic acid	2.8.	Biphenyl	0.30
Pentanoic acid	33	Chrysene	3.0×10^{-4}
Phenol	8.5	Dibenzofuran	0.40
Propanoic acid	67	Ethylbenzene	85
Pyridine	0.55	Fluoranthene	0.030
Resorcinol	97	Indan	4.0
2-Methylphenol	2.3	Methanethiol	33
2-Methylpropionic acid	5.5	Naphchalene	1.4
2-Methylpyridine	3.3	Perylene	6.lx10 ⁻⁵
2,4-Dimethylpyridine	0.046	Phenanthrene	0.015
2,4-Xylenol	2.0	Pyrene	0.030
2,5-Dimethylpyridine	0.046	Quinoline	0.43
3-Methylbutanoic acid	2.8	Toluene	280
3-Methylphenol	1.4	o-Xylene	⁻ 97
3-Methylpyridine	1.2		

enriched on the surface of vegetation and in soils within one or two km of the plant. Over the life of the plant, salts, metals, and the more persistent PAH's may reach concentrations in the soil deleterious to soil communities, vegetation, and animals.

Stream 29 is expected to release far more organic contaminants, As, Be, Cd, Pb, and TDS than the stack gases (Stream 28). Stream 28 will release more SO_x and NO_x . On the basis of relative release rates, the presence of substantial levels of organics, the problem of drift, and the uncertainties surrounding the stream itself, Stream 29 appears to represent the most important short-term threat (among atmospheric emissions) to local terrestrial and aquatic ecosystems, while Stream 28 may represent an important regional stress.

Finally, in common with most coal conversion technologies, cooling towers and other plant operations of the model plant require a source of make-up water. Although a detailed evaluation of the effects of make-up water diversion is beyond the scope of this study, it should be noted that such diversion can adversely affect aquatic ecosystems. Make-up (Stream 31) for the study plant is projected to be 149-1/s (5.25 cfs). Withdrawals of this magnitude would constitute a problem only in small streams where significant ecological harm through entrainment of organisms and reductions of downstream flow and carrying-capacity could occur.

3.3 LOCKHOPPER VENT GAS EMISSIONS (Stream 72)

Table 3-4 shows post-dilution concentrations in air, and known toxic concentrations for some of the most important contaminants or classes of contaminants likely to occur in lockhopper vent gas emissions. Most of the contaminants for which information was available are expected to be released at rates lower than those expected from either or both of the other two principal atmospheric waste streams. The implications for the health of local ecosystems are unknown. This waste stream's importance as a potential hazard to local and regional

TABLE 3-4: LOCKHOPPER VENT GAS EMISSIONS (STREAM 72): COMPARISON OF PROJECTED POST-DILUTION ENVIRONMENTAL CONCENTRA-TIONS WITH ECOLOGICAL BENCHMARKS

• • • • •

:

. •

i

	A	8	A/B
	Estimated	Toxic	
•	Post-	Conc.	
	Conc.	((42 / 24)	
	(ug/a ³) ^a		
TRACE ELEVENTS			· · ·
Aluminum	<u> </u>	;	
Arsenic	1	·	
Bervllium	1	· · ·	
Boron	1	<u></u>	
Cadmium	[<u> </u>	
Copper	<u>!</u>	<u> </u>	
Fluorine	<u> </u>	<u> </u>	
Iron	<u> </u>	<u> </u>	
Lead		<u>i</u> i	i
Manganese		! <u> </u>	
Mercury	i	·	
Nickel	1		
Selenium	:	n in I	
Vanadiuz	1	'	
Zine	<u> </u>	1 1	
TOTAL TRACE ELEMENTS	1 2.5E-2	5.05-141	5-05-2
ALIPHATICS. ALICYCLICS	1	1	
AND FATTY ACIDS	İ.,		
Aceric Acid			
Buzanoic Acid	<u>i</u>	<u> </u>	~
Hexancic Acid	Į	lı	
3-Methylbutenoic Acid	i	l!	_
2-Methylpropanoic Acid	!		
Pentanoic Acid	1	II	
Propanoic Acić	i	1	
TOTAL FATTY ACIDS	I 1.3E-1	1 <u>2.02+4</u> :	6.35-6
SENZENES & SUBSTITUTED			
Bipheavl			
Ethylbenzene			
Indan	1		
Toluene			
1.2.4-Trizethrlb-szene	1		
Dairy and	1	I [

38

...

.

13

TABLE 3-4 (continued)

.

- .

		· · · · · · · · · · · · · · · · · · ·	
	Å	Вы	4/9
	Estimated	Toxic	1
	Post-Dilu-		
	Conc.	(µ¤/=-')	
	(2g/m ³) ^a	Ì]
PHENOLS		i	
Cacechol	<u> </u>	;	
3,6-Dimethylcatechol	<u> </u>	!	
3-Methylcatechol	<u> </u>	1	
4-Methylcatechol			
2-Methylphenol			
3-Methvlohenol			
4-Methylphenol		· .	
4-Methvlresorcinol			
5-Methylresorcinol			<u>.</u>
Phenol	<u> </u>		·
Resorcinel	1		
2.4-Xvlenol		i	
3.5-Xvienol			
TOTAL PRENOLS	6.4E-1	1.0E+2	6.4E-1
POLYDEICE TAR AROMATTC	1	······	
SYDROCARBONS			
Acenaphchalene	<u>}.</u>		
Anthracene	1	<u> </u>	
Benz(a)anthracene	i		
Benzo(g,h,i)perviene	<u>i</u>	l	
Benzo(a) ovrene		i	
Senzo(a) pyrene	· ·	ł	
Chrysene	1	i	
Fluoranthene	<u>i</u>		•
Fluorene	1	•	
Nachthalene	1	1	
Pervlene	1		:
· Phenanchrene	1	1	:
Pyrene	1	!	1
TOTAL PAR'S	2.45-2	. 9E-4	3.02-7
SULFUR HETEROCYCLICS	1 .	1	İ
Methyl thiothene	<u> </u>	<u> </u>	
Thiothene	1	1	1
TOTAL THIOPHENES	1 2.78-1	1,05-1	4." <u>7</u> .3

ę ,

 $\hat{\mu}$

.

TABLE 3-4 (continued)

ومحمد المتحد المتحديد فالمناكر بوالمحم			
	A	a	A/ 8
	Estimated	Toxic	
	Post-	Conc.	
	Diution	(_{F8} /¤3)	
	(ug/m ³)		
NITROGEN HETEROCYCLICS			
2.4-Dimethylpyridine			
2.5-Dimethylpyridine			
2-Methviovridine	<u> </u>		
3-Methvlovridine	!	-	
4-Methylpyridine		•	
Pvridine		1	I
Ouinoline	i	••	
OXYGEN HETEROCYCLICS			
Benzofuran		÷	
Dibenzofuran			i
MERCAPTANS			
` Hechanethiol			
TOTAL MERCAPTANS	2.3E-1	2.0E+7	i 1.3E-3
AROMATIC AMINES .			
Aniline	.		l
TOTAL AROMATIC AMINES	4.85-2	÷.4-5	i 1.1E-7
NITROSAMINES	2.4E-2	4.3E+4	5.0E-7
MISCELLANEOUS			
Amonia	1.0E+2	1.02+3	9.92-2
Carbonvl Sulfide	1.4	7.1E+6	÷ 2.0E-7
Bydrogen Canide	9.5E-2	, ∴.∴E÷1	2.22-3
Hydrogen Sulfide	i 6.52+1	2.52+4	2.42-3
Nickel Carbonyl	1 7.22-2	•	ì .
NC	1	: ,	:
Zarticulates		1	1
SOv	1		!
	- 1547	·	1

^aBased on dilution factor of 24,000 derived from SAM/1 model²²¹.

^bPublished toxicities regardless of species, endpoint, and exposure conditions. In case of classes (e.g., PAH's) toxicities are for specific compounds (e.g., naphthalene)35, 36, 130, 215

^CValue is for Vanadium³⁴.

ecosystems lies primarily in its added contributions to the pollutant loading from the other atmospheric emissions. Post-dilution concentrations of none of the contaminants exceeded the toxic benchmarks used in the analysis, although the total post-dilution concentrations of tars, oils, and naphtha (735 $\mu\,g/m^3)$ easily exceed the national primary ambient air quality standard of $\mu g/m^2$ for non-methane 160 hydrocarbons. Based on the calculated ratio of post-dilution concentrations to benchmarks, total phenols, total trace elements, and ammonia appear to pose relatively greater hazards than other stream components.

4 SUMMARY AND CONCLUSIONS

This volume has attempted to assess selected aqueous and atmospheric emissions from the gasification phase of a Lurgi/Fischer-Tropsch facility, presumed to pose the most significant hazards to aquatic and terrestrial ecosystems. These streams were selected on the basis of the preliminary characterization of the stream constituents and the likelihood of their entering the environment. The scarcity of empirical data on waste stream composition, individual contaminant toxicities (both acute and chronic), and environmental behavior, in conjunction with the great variability in the many blotic and nonbiotic elements of a receiving ecosystem, has made identification of ecological effects and ranking of waste streams according to hazard potential uncertain, at best.

A number of assumptions were made to arrive at conservative, though not necessarily worst-case estimates of the hazard potential of the selecte streams. Within limitations of the stated assumptions for aqueous emissions, Stream 53, reverse osmosis waste, appears to pose the greatest hazard because of its relatively high concentration of trace elements and the presence of organics. Cadmium and mercury both exceed the lowest observed toxic concentrations by a factor of several The organics within Stream 53 which occur at levels hundred. potentially hazardous to equatic organisms are resorcinol, naphthalene, methanethiol, hexanoic acid, and catechol. phenol, Stream 70, biosludge, is the aqueous stream next in order of apparent ecological hazard, having levels of cadmium, mercury and naphthalene which could present significant hazards to aquatic ecosystems. Of the three aqueous streams, ash leachate (Stream 70) appears to be the least hazardous.

Within, limitations of stated assumptions for atmospheric emissions, Stream 29, cooling tower evaporative losses and drift, appears to pose the greatest hazard to receiving ecosystems on the basis of the quantities of both organic and inorganic contaminants released, and the mode of release (both drift and vapor). Next in order of

apparent ecological hazard is Stream 28, the utility stack gases, which will release relatively high levels of SO_x , NO_x , and Hg. Finally, the lockhopper vent gases (Stream 72) will release pollutants, contributing to many of the individual atmospheric pollutant levels generated by Streams 28 and 29. All three of these gaseous discharge streams appear to have the potential for exceeding established or proposed standards or criteria for one or more contaminants after dilution in the atmosphere.

Aside from the need for additional data on the constituents of the six selected streams, perhaps the greatest need (and at the same time the most serious constraint on the ability to evaluate the environmental effects of indirect coal liquefaction) is to understand the acute and chronic effects of whole stream emissions and the linteractions (synergistic, antagonistic, and additive) among constituents within streams and among streams. This need cannot be fully met until full-scale operating units produce waste streams that can be thoroughly characterized physically, chemically, and in terms of their biological and ecological activity.

F

43

÷.,

- Committee on Medical and Biological Effects of Environmental Pollutants, <u>Selenium</u>, National Academy of Sciences, Washington, DC, 1976.
- 13. Committee on Water Quality Criteria, <u>Water Quality Criteria</u>, <u>1972</u>, National Academy Sciences, National Academy Engineering, Environmental Protection Agency, Washington, DC, 1973.
- 14. Cushman, R.M., S.G. Hildebrand, R.H. Strand, and R.M. Anderson, <u>The Toxicity of 35 Trace Elements in Coal to Freshwater</u> <u>Biota: A Data Base with Automated Retrieval Capabilities</u>, <u>ORNL/TM-5793</u>, Oak Ridge National Laboratory, Oak Ridge, TN, 1977.
- Dawson, G.W., <u>The Chemical Toxicity of Elements</u>, BNWL-1815 UC-70, Battelle Pacific Northwest Laboratories, Richland, WA, 1974.
- 16. Energy Reserach and Development Administration, Effects of Trace Contaminants from Coal Combustion. Proceedings of a Workshop, R.I. Van Hock and W.D. Shults, eds., August 2-6, 1976, Knoxville, TN.
- Fish and Wildlife Service, Impacts of Coal-Fired Power Plants on Fish, Wildlife, and their Habitats, U.S. Dept. of Interior, FWS/OBS-78-29, Argonne National Laboratory, 1978.
- 18. Ghassemi, M., K. Crawford, and S. Quinlivan, <u>Environmental</u> <u>Assessment Report: Lurgi Coal Gasification Systems for SNG</u>, <u>EPA-600/7-79-120</u>, prepared for U.S. EPA by TRW, Inc., May 1979.
- Giddings, J.M., Unpublished data on acute toxicity of coal organics to algae, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.
- Gluskoter, H.J., <u>Trace Elements in Coal: Occurrence and</u> <u>Distribution</u>, Illinois State Geological Survey, Circular 499, Urbana, IL, 1977.
- 21. Greenwood, D.R., G.L. Kingsbury, and J.G. Cleland, <u>A Handbook of Key Federal Regulations and Criteria for Multimedia</u> Environmantal Control, EPA-600/7-79-175, Washington, DC 1979.
 - 22. Griffin, R.A., R.M. Schuller, S.T. Rossel, and N.F. Shimp, "Solubility and Toxicity of Potential Pollutants in Solid Coal Wastes", in <u>Environmental Aspects of Fuel Conversion</u> Technology III, EPA-600/7-78-063, April 1978.

- 23. Heit, M., A Review of Current Information on Some Ecological and Health Related Aspects of the Release of Trace Metals into the Environment Associated with the Combustion of Coal, Health and Safety Laboratory, U.S.E.R.D.A. NY, 1977.
- 24. Herbes, S.E., G.R. Southworth, and C.W. Gehrs, "Organic Contaminants in Aqueous Coal Conversion Effluents: Environmental Consequences and Research Priorities," in <u>Trace</u> <u>Substances in Environmental Health - A Symposium</u>, University of Missouri, Columbia, MO, 1976.
- 25. Hildebrand, S.G., and R.M. Cushman, "The Potential Toxicity and Bioaccumulation in Aquatic Systems of Trace Elements Present in Aqueous Coal Conversion Effluents," in <u>Proceedings</u> of <u>Tenth Annual Conference on Trace Substances in</u> <u>Environmental Health</u>, June 8-10, 1976, pp. 305-313, University of MO, Columbia, Missouri, 1976.
- Hohreiter, D.W., <u>Toxicities of Selected Substances to Freshwater</u> <u>Biota</u>, ANL/ES-94, Argonne National Laboratory, Argonne, IL, 1980.
- 27. Klein, D.H., and P. Russell, "Heavy Metals: Fallout Around A Power Plant," <u>Environmental Science and Technology</u>, 7:357-358, 1973.
- Klein, T.A., Personal communication, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.

- 29. Kopp, J.F., and R.C. Kroner, <u>Trace Metals in Waters of the</u> <u>United States: A Five-year Summary of Rivers and Lakes of</u> <u>the United States (Oct. 1, 1962 - Sept. 30, 1967),</u> U.S. Dept. of the Interior, Federal Water Pollution Control Administration, Cincinnati, OH, 1967.
- 30. McKee, J.E., and H.W. Wolf, (eds.), <u>Water Quality Criteria</u>, Second edition, Publication Number 3-A, California State Water Quality Control Board, Sacramento, CA, 1963.
- 31. Moles, A., "Sensitivity of Parasitized Coho Salmon Fry to Crude Oil, Toluene, and Naphthalene," <u>Transactions of the</u> <u>American Fishery Society</u>, 109:293-297, 1980.
- 32. Oak Ridge National Laboratory, Environmental, Health, and Control Aspects of Coal Conversion: An Information Overview, Vols. 1 and 2, H.M. Braunstein, E.D. Copenhaver, and H.A. Pfuderer (eds.), Oak Ridge, TN, ORNL/EIS-95, 1977.

- 33. Oak Ridge National Laboratory, Environmental and Health Aspects of Disposal of Solid Wastes from Coal Conversion: An Information Assessment, H.M. Braunstein, (ed.), ORNL-5361, Oak Ridge, TN, 1978.
- 34. Oak Ridge National Laboratory, <u>Life Sciences Synthetic Fuels</u> <u>Progress Report.</u> 1980, Fossil Energy Quarterly Progress Report for the period ending December 31, 1979, Oak Ridge, TN, ORNL-5360, 1980.
- 35. Parker, C.L., and D.I. Dykstra, <u>Environmental Assessment Data Base</u> for Coal Liquefaction Technology: Volume I, Systems for <u>Fourteen Liquefaction Processes</u>, EPA-600/7-78-184a, prepared for U.S. EPA by Hittman Associates, Columbia, MD, September 1978.
- 36. Parker, C.L., and D.I. Dykstra, Environmental Assessment Data Base for Coal Liquefaction Technology, Volume II, EPA-600/7-78-184b, prepared for U.S. EPA by Hittman Associates, Columbia, MD, September 1978.
- 37. Parkhurst, B.R., Unpublished data on acute toxicity of coal organics to <u>Daphnia magna</u>, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.
- 38. Parkhurst, B.R., A.S. Bradshaw, J.L. Forte, and G.P Wright, "An Evaluation of the Acute Toxicity to Aquatic Biota of a Coal Conversion Effluent and its Major Components," <u>Bulletin</u> of Environmental Contamination Toxicology, 23:349-356.
- Radian Corporation, <u>Coal Fired Power Plant Study: A Three</u> <u>Station Comparison. Vol. I, Environmental Protection Agency,</u> PB-257293, Denver, CO, 1975.
- 40. Sanders, F.S., <u>Draft: Guidance for the Use of Artificial Streams</u> to Assess the Effects of Toxicants in Freshwater Systems, ORNL/TM-7185, Oak Ridge National Laboratory, Oak Ridge, TN.
- 41. Shriner, D.S., H.S. Arora, N.T. Edwards, B.R. Parkhurst, C.W. Gehrs, and T. Tamura, "Physical, Chemical and Ecological Characterization of Solid Wastes from a Lurgi Gasification Facility", in <u>Symposium on Potential Health and Environmental</u> <u>Effects of Synthetic Fossil Fuel Technologies</u>, Oak Ridge National Laboratory, Oak Ridge, TN, July 1979.
- 42. Singer, P.C., F.K. Pfaender, T. Churchilli, A.F. Maclorowski, J.C. Lamb, and R. Goodman, <u>Assessment of Coal Conversion Waste</u> <u>Waters:</u> <u>Characterization and Preliminary Biotreatability</u>, <u>EPA-600/7-78-181</u>, prepared for the U.S. EPA by the University of North Carolina, September 1978.

- 43. Somerville, M.H., and J.L. Elder, "A Comparison of Trace Element Analyses of North Dakota Lignite Laboratory Ash with Lurgi Gasifier Ash and Then Use in Environmental Analyses," in <u>Symposium Proceedings: Environmental Aspects of Fuel</u> <u>Conversion Technology III</u>, EPA-600/7-78-063, U.S. EPA, April 1978.
- 44. Stoker, H.S., and S.L. Seager, <u>Environmental Chemistry: Air and</u> <u>Water Pollution</u>, 2nd jed, Scott, Foresman and Company, Glenview, IL, 1976.
- 45. Triegel, E.K., <u>Attenuation by Soils of Selected Potential</u> <u>Contaminants from Coal Conversion Facilities: A Literature</u> <u>Review, ORNL/TM-7249, Oak Ridge National Laboratory, Oak</u> <u>Ridge, TN, 1980.</u>
- 46. U.S. Department of Health, Education, and Welfare, <u>Air Quality</u> <u>Criteria for Sulfur Oxides</u>, Natational Air Pollution Control Administration No. AP-50, Washington, DC, 1970.
- 47. U.S. Environmental Protection Agency, <u>Environmental Assessment:</u> Source Test and Evaluation Report: Wellman-Galusha (Glen Gery) Low-Btu Gasification, EPA-600/7-79-185, 1979.
- 48. U.S. Environmental Protection Agency, "EPA Interim Primary and Proposed Secondary Drinking Water Standards," Appdx. II <u>Federal Register</u>, 43(243):59019, December 18, 1978.
- 49. U.S. Environmental Protection Agency, "Hazardous Waste: Proposed Guidelines and Regulations and Proposal on Identification and Listing," 40 CFR Part 250, <u>Federal Register</u>, 43(243), December 18, 1978.

e,

े

- 50. U.S. Environmental Protection Agency, <u>Quality Criteria for</u> Water, EPA 440/9-76-023, Washington, DC, 1976.
- 51. U.S. Environmental Protection Agency, "Water Quality Criteria; Availability," <u>Federal Register</u>, 44(144):43660-43697, July 25, 1979.
- 52. U.S. Environmental Protection Agency, "Water Quality Criteria; Availability," Federal Register, 44(191):56628-56657, October 1, 1979.
- U.S. Environmental Protection Agency, "Water Quality Criteria; Request for Comments," <u>Federal Register</u>, 44(52):15926-15981, March 15, 1979.

- 54. Vaughan, B.E., K.H. Able, D.A. Cataldo, J.M. Hales, C.E. Hane, L.A. Rancitelli, R.C. Routson, R.E. Wildung, and E.G. Wolf, <u>Review of Potential Impact on Health and Environmental</u> <u>Quality from Metals Entering the Environment as a Result of</u> <u>Coal Utilization</u>, Battelle Pacific Northwest Laboratories, Richland, WA, 1975.
- 55. Verschueren, K., <u>Handbook on Environmental Data on Organic</u> <u>Chemicals</u>, Van Nostrand Reinhold Co., Atlanta, GA, 1977.
- 56. Waterland, L.R., and L.B. Anderson, "Source Analysis Models for Environmental Assessment," in <u>Symposium Proceedings:</u> <u>Environmental Aspects of Fuel Conversion Technology, IV,</u> Hollywood, FL, pp. 23-34, EPA-600/7-79-217, April 1979.
- 57. Weeter, D.W., and M.P. Bahor, <u>Technical Aspects of the</u> Resource Conservation and Recovery Act Upon Coal Combustion and Conversion Systems, ORNL/OEPA-10, Oak Ridge National Laboratory, Oak Ridge, TN, 1979.

49

į,

LIST OF TABLES

Table Number

5

Page

- 2-1 Gasifier Ash Leachates (Streams 36 and 69): Comparison of Projected Post-Dilution Environmental Concentrations (of Westfield Coal Ash Leachate) with Ecological Benchmarks
- 2-2 "Worst Case" Gasifier Ash Leachates (Stream 69): Comparison of Projected Post-Dilution Environmental Concentrations of Substances in a Hypothetical Leachate that have the Highest Concentration Found in a Literature Search of Leachates from Gasifier Ash (Regardless of Coal or Specific Process) with Ecological Benchmarks

.

2-3 Reverse Osmosis Waste (Stream 53): Comparison

APPENDIX

Summaries^{*} of transport, transformation, and fate of selected trace elements and organic compounds expected to occur in waste streams from indirect coal liquefaction.

Table	Compound/
Number	Element
1 .	Antimony
2	Arsenic
3	Beryllium
4	Cadmium
5	Chromium
6	Copper
7 .	Cyanide
8	Lead
9 h	Mercury
10	Nickel
11	Selenium
12 .	Silver
13	Thallium .
14	Zinc
15	Acenaphthylene
16	Anthracene
17	Benzene
18	Benzo(a)anthracene
19	Benzo(g,h,i)perylene
20	Benzo(a)pyrene
21 .	Chrysene
22	Dimethylnitrosamine
23	2,4-Dimethylphenol
24	Diphenylnitrosamine
25	Di-n-Propylnitrosamine
26	Ethylbenzene
27	Fluorene
28	Naphthalene
29 [·]	Phenanthrene
30	Phenol
31	Pyrene
32	Toluene

*Reproduced from Callahan, M.A., <u>et.</u> <u>al.</u>, <u>Water-Related Environmental Fate of</u> <u>129 Priority Pollutants</u>, Vols. I and II, EPA-440/4-79-029a and EPA-440/4-79-029b, 1979.

1

A-1

REFERENCES

- American Fisheries Society, <u>A Review of the EPA Red Book:</u> <u>Quality Criteria for Water</u>, Water Quality Section, American Fisheries Society, Bethesda, MD, 1979.
- Biesinger, K.E., and G.M. Christensen, "Effects of Various Metals on Survival, Growth, Reproduction and Metabolism of <u>Daphnia</u> magna," in <u>Journal of Fisheries Research Board of</u> Canada, 29(12):1691-1700, 1972.
- 3. Boston, C.R., and W.J. Boegly, Jr., "Leaching Studies on Coal and Coal Conversion Wastes," in <u>Energy and the</u> <u>Environment</u>, Proceedings of the 6th National Conference, May 21-24, 1979, Pittsburgh, PA, 1979.
- 4. Bowen, H.J.M, <u>Environmental Chemistry of the Elements</u>, Academic Press, New York, NY, 1979.
- Brown, D.K., Personal communication regarding UMD gasifier ash leachates, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.
- Brown, D.K., E.C. Davis, and H.W. Wilson, Personal communications, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.
- 7. Callahan, M.A, et al., Water-Related Environmental Fate of 129 Priority Pollutants, Vols. I and II, EPA-440/4-79-029a and EPA-440/4-79-029b, 1979.
- Cleland, J.G., and G.L. Kingsbury, <u>Multimedia Environmental Goals</u> for Environmental Assessment, Vol. I, EPA-600/7-77-136a, 1977.
- Cleland, J.G., and G.L. Kingsbury, <u>Multimedia Environmental Goals</u> for Environmental Assessment, Vol. II, EPA-600/7-77-136b, 1977.
- Cleland, J.G., and G.L. Kingsbury, <u>Multimedia Environmental Goals</u> for Environmental Assessment, Vol. III, EPA-600/7-79-176a, 1979.
- Cleland, J.G., and G.L. Kingsbury, <u>Multimedia Environmental Goals</u> for Environmental Assessment, Vol. IV, EPA-600/7-79-176b, 1979.

.

SUMMARY OF AQUATIC FATE OF ANTIMONY

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Not important.	Low
Chemical Speciation*	Antimony is present as the soluble oxide or antimonite salt in most natural waters. In reducing environments, vola- tile SbH ₃ may be formed. Most species of antimony are soluble and mobile in the aquatic environment.	Medium .
Volatilization	Important where SbH3 is stable.	Medium
Sorption [*]	Antimony is adsorbed by clays and organic materials.	Low
Bioaccumulation	Very slight.	Medium
Biotransformation*	Biomethylation may occur.	Low

All of the noted environmental processes are important; however, their * relative importance with respect to each other is uncertain for determining final fate. 1 .

.

٠

.

:

SUMMARY OF AQUATIC FATE OF ARSENIC

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Not an important process.	Medium
Chemical Speciation*	Important in determining arsenic distribution and mobility. Interconversions of +3 and +5 state and organic complexation are most important.	High
Volatilization [*]	Important when biological activity or highly reducing conditions produce AsH ₃ or methylarsenics.	High
Sorption [*]	Sorption onto clays, iron oxides, and organic material is a controlling mechanism for the fate of arsenic in the aquatic environment.	High .
Bioaccumulation*	Appears to be most significant in lower trophic levels. High toxicity lowers overall accumulation by aquatic organisms.	Medium
Biotransformation*	Arsenic is metabolized by a number of organisms to organic arsenicals, thereby increasing arsenic mobility in the environment.	High

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

.

SUMMARY OF AQUATIC FATE OF BERYLLIUM

Environmental Process	Summary Statement	Confidence ofData
Photolysis	Not an important fate.	Low
Chemical Speciation*	Beryllium is hydrolyzed to form insoluble compounds. A controlling mechanism for beryllium in the aquatic environment.	Medium
Volatilization	Not an important fate.	Low
Sorption [*]	Probably adsorbed by clays and other mineral surfaces at low pH.	Low
Bioaccumulation .	Slight accumulation by aquatic organisms. No food chain magnification in evidence.	Medium
Biotransformation	Unreported.	Low

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

:

•

A-4

:.

SUMMARY OF AQUATIC FATE OF CADMIUM

v

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Not an important process.	High
Chemical Speciation*	In most unpolluted waters the majority of the cadmium will exist as the hydrated divalent cation. In polluted waters, complexation with organic material will be most important. Affinity of ligands for cadmium follows the order of humic acids $>CO_3^2 - >OH - >C1 - >SO_4^2$.	Medium
Volatilization	Not an important process.	High '
Sorption*	Various sorption processes reduce the mobility of cadmium and result in the enrichment of suspended and bed sediments relative to the water column. In unpolluted waters, sorption onto clay minerals, and hydrous iron and manganese oxides are controlling factors. In polluted waters, sorption onto organi-	High
Bioaccumulation*	Biota strongly accumulate Cd with concentration factors ranging from 10^2 to 10^4 or more. Bioaccumulation is greater in soft than hard water.	High
Biotransformation	No biomethylation in evidence. Organic ligands of biological origin may affect solubility and adsorption.	Medium

* All of the noted environmental processes are important however, their relative importance with respect to each other is uncertain for determining final fate.

TABLE 5 -

SUMMARY OF AQUATIC FATE OF CHROMIUM

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Not an important process.	Medium
Chemical Speciation	An important consideration in the aquatic fate of chromium. Controls the intertransformation of Cr(VI) to Cr(III). Cr(VI) remains soluble, while Cr(III) will hydrolyze and precipitate as Cr(OH) ₃ .	Medium
Volatilization	Not an important process.	Medium
Sorption [*]	Cr(III) is adsorbed weakly to inorganic materials. Cr(VI) may be adsorbed by organic materials.	Medium
Bioaccumulation [*]	As an essential nutrient, chromium is bioaccumulated by a variety of aquatic organisms. May be trans- ferred via the food chain.	High
Biotransformation	Probably not important.	Low

* All of the noted environmental processes are important: however, their relative importance with respect to each other is uncertain for determining final fate.

A-6

ı,

A--7

١.

4

SUMMARY OF AQUATIC FATE OF COPPER

Environmental	Summary	Confidence of
Process	Statement	Data ·
Photolysis	Not an important process.	Medium
Chemical Speciation*	In most unpolluted waters, the majority of copper will exist as the carbonate complex. In polluted waters, complexation with organic material will be most important.	Medium
Volatilization	Not an important process.	High
Sorption [*]	Various sorption processes reduce the mobility of copper and result in the enrichment of suspended and bed sediments relative to the water column. In unpolluted waters, sorption onto clay minerals, and hydrous iron and manganese oxides are controlling factors. In polluted waters, sorption onto organic materials is the controlling factor.	• High
Bioaccumulation*	Biota strongly accumulate copper. Copper is apparently not biomagni- fied.	High .
Biotransformation	Some copper complexes may be metabolized. Organic ligands are important in sorption and complexation processes.	Medium

* All of the noted environmental processes are important: however, their relative importance with respect to each other is uncertain for determining final fate.

SUMMARY OF AQUATIC FATE OF CYANIDE

Environmental Process	Summary Statement	Confidence of Data
Photolysis [*]	Can cause breakdown of some metallocyanide complexes.	Medium
Chemical Speciation	Chemical transformations occur very slowly in most aquatic environments.	Medium
Volatilization*	At pH<10 most of the free cyanide will be HCN which is quite volatile. A most important process in the aquatic environment.	Medium
Sorption "	Cyanides are sorbed by organic materials and to a lesser extent clay minerals. Not an important process.	Low
Bioaccumulation	Cyanides are not bioaccumulated.	Medium
Biotransformation*	Cyanides are biodegraded at low concentrations by almost all organisms. A very important process for the aquatic fate of cyanides.	Medium

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

-

4

SUMMARY OF AQUATIC FATE OF LEAD

Environmental Process	Summary Statement	Confidence of Data
Photolysis [*]	Important in determining the form of lead entering the aquatic environment. Importance within natural waters in undeterminable.	Medium
Chemical Speciation [*]	Determines which solid species controls solubility in unpolluted waters. Over most of the normal pH range, PbCO ₃ and PbSO ₄ control solubility in aerobic conditions. PbS and Pb control solubility in anaerobic conditions. In polluted waters, organic complexation is most important.	Medium
Volatilization	Probably not important in most aquatic environments.	Medium
Sorption [*]	Adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead.	High
Bioaccumulation*	Lead is bioaccumulated by aquatic organisms. Bioconcentration factors are within the range of $10^2 - 10^3$.	High
Biotransformation [*]	Biomethylation in sediments can remobilize lead.	Medium

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

¢,

A-9

SUMMARY OF AQUATIC FATE OF MERCURY

Environmental	Summary	Confidence of
Process	Statement	Data
Photolysis*	Important in the breakdown of airborne mercurials, might be important in some aquatic environments.	Medium
Chemical Speciation*	Controls volatility of metallic mercury by conversion to complexed species. In reducing sediments HgS will precipitate and may constitute a major chemical sink.	High
Volatilization [*]	Important to the movement of mercury compounds in and out of the aquatic environment.	High
Sorption [*]	Sorption processes result in the strong partitioning of mercury into suspended and bed sediments. Sorption is strongest into organic materials.	High
Bioaccumulation	Bioaccumulation has been proven to occur via numerous mechanisms. Most are connected to methylated forms of mercury.	High
Biotransformation*	Mercury can be metabolized by bacteria to methyl and dimethyl forms which are quite mobile in the environment.	High

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

:

SUMMARY OF AQUATIC FATE OF NICKEL

Environmental . Process	Summary Statement	Confidence of Data
Photolysis	Not an important process.	Medium
Chemical Speciation*	In aerobic environments below pH 9, soluble compounds are formed with hydroxide, carbonate, sulfate and organics. Above pH 9, precipita- tion of the hydroxide or carbonate will occur. In reducing environ- ments, NiS will precipitate. Not a regulating factor in most waters.	Medium -
Volatilization	Not an important process.	Medium
Sorption ⁴	Nickel is the most mobile of the heavy metals. Coprecipitation with hydrous metal oxides, sorption into organic material, and ion exchange with crystalline minerals are the dominant factors which affec its mobility.	High
Bioaccumulation	Reported bioconcentration factors are on the order of 10^2-10^3 . Not a dominant process.	Medium
Biotransformation	Not an important process.	Medium

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

ł.

SUMMARY OF AQUATIC FATE OF SELENIUM

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Not an important process.	Low
Chemical Speciation [*]	Controls solubility. Under anaerobic conditions and/or low pH, insoluble elemental selenium is formed. Under other conditions, soluble complexes are formed.	Medium
Volatilization [*]	May occur via biomethylation or formation of H ₂ Se.	Medium
Sorption [*] :	Hydrous metal oxides sorb selenium strongly. Clays and organic materials have a lesser affinity.	Medium .
Bioaccumulation [*]	Concentration ratios depend on chemical form in soils and organism.	Medium
Biotransformation [*]	Metabolism may result in methylation with subsequent volatilization.	Medium

* All of the noted environmental processes are important; however, their relative importance with respect to each other is uncertain for determining final fate.

SUMMARY OF AQUATIC FATE OF SILVER

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Probably not important in determining fate.	Low
Chemical Speciation*	Chloride, bromide and iodide ions control the levels of hydrated silver cations. Crystalline, metallic silver and silver sulfides may precipitate under reducing conditions.	Medium
Volatilization	Not an important fate.	Medium
Sorption [*]	Silver is strongly sorbed by hydrous manganese and iron oxides, clay minerals and organics. A major controlling mechanism in determining the fate of silver in the aquatic environment.	High
Bioaccumulation*	Numerous plants and primary consumer organisms accumulate silver. Little evidence to suggest bicmagnification	High
Biotransformation	Probably not an important fate.	Medium

. 2

* All of the noted environmental processes are important: however, their relative importance with respect to each other is uncertain for determining final fate.

SUMMARY OF AQUATIC FATE OF THALLIUM

Environmental	Summary	Confidence of
Process	Statement	Data
Photolysis	Not an important mechanism.	Medium
Chemical Speciation [*]	In reducing environments Tl(I) may precipitate as a sulfide: otherwise, it will remain in solution.	Medium
Volatilization	Not an important mechanism.	Low
Sorption [*]	Thallium is adsorbed to clay minerals and hydrous metal oxides. Probably a very important process.	Medium
Bioaccumulation*	Thallium is accumulated by aquatic organisms. Probably an important process.	Low
Biotransformation	Not an important process.	Lòw

* All of the noted environmental processes are important: however, their relative importance with respect to each other is uncertain for determining final fate.

• .

ŵ
SUMMARY OF AOUATIC FATE OF ZINC

Environmental Process	Summary Statement	Confidence of Data
Photolysis	Not an important mechanism.	, Medium
Chemical Speciation*	In most unpolluted waters, the majority of zinc will exist as the hydrated divalent cation. In polluted waters, complexation will predominate.	Medium .
Volatilization	Not an important mechanism.	Medium
Sorption [*]	Zinc has a strong affinity for hydrous metal oxides, clays, and organic matter. Adsorption increases with pH.	High
Bloaccumulation [*]	Zinc is strongly bioaccumulated. Bioconcentration factors range from 10^2 to 10^5 .	High
Biotransformation	No biomethylation in evidence. Organic ligands of biological origin may affect solubility and adsorption.	Medium

* All of the noted environmental processes are important: however, their relative importance with respect to each other is uncertain for determining final fate.

.

A-15

SUMMARY OF AQUATIC FATE OF ACENAPHTHYLENE

Environmental Process	Summary Statement**	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis	Dissolved portion may undergo rapid photolysis.			
Oxidation	Oxidation of PAH by RO ₂ ° radical is a slow process; not a significant process.			
Hydrolysis	PAHs do not contain groups amenable to hydrolysis.			
Volatilization .	Is probably not as importan as adsorption as a transpor process.	t		
Sorption ^{††}	Measured adsorption coeffi- cients for PAH and suspende solids are high; movement via sediment is considered important transport process PAH.	d an for		
Bioaccumulation	A short-term process; PAHs with less than 4 ot 5 rings are readily metabolized and long-term partitioning into biota is not a significant fate process.			
Biotransformation/ Biodegradation	PAHs with less than 4 rings are degraded by microbes an are readily metabolized by multicellular organism: bio degradation is probably the ultimate fate process.	d 		

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

- ** Very little environmental fate data specific to acenaphthylene were found; the summary statement is made from data reviewed for PAHs as a group.
- † Data on acenaphthylene are not sufficient to permit confidence ranking. The confidence of the data reviewed for PAHs in general ranges from low to high.
- †† Because the solubility of this compound is relatively high, 50 percent or more may exist in true solution under conditions of normal sediment loading (Southworth 1979).

SUMMARY OF AQUATIC FATE OF ANTHRACENE.

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis	Dissolved portion may undergo rapid photolysis.	-	35 minutes	: Medium
Oxidation	Oxidation of anthracene by RO ₂ radical is slow; not a significant process	50 mol sec	1600 days	Medium
Hydrolysis	Anthracene does not con- tain groups amenable to hydrolysis.	Ŭ	-	Medium
Volatilization	May be competitive with adsorption.	.0.002 to 0.179 hr	18-300 hrs 1	tow
Sorption**	Measured adsorption coefficients for anthracene and sus- pended solids are high; movement via sediment is considered to be an important transport process.			Medium
Bioaccumulation	A short-term process; anthracene is readily metabolized and long- term partitioning into biota is not a signi- ficant fate process.	-	· _	Medium
Biotransformation/ Biodegradation	Anthracene can be degraded by microbes and is readily meta- bolized by multi-cellular organisms; biodegration is probably the ultimate fate process.	<0.0612 hr	¹ >11.3 hr:	s Medium

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

** Because the solubility of this compound is relatively high, 50 percent or more may exist in true solution under conditions of normal sediment loading. Southworth (1979).

SUMMARY OF AQUATIC FATE OF BENZENE

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis "	Since the ozone layer in the upper atmos- phere effectively fil- ters out wavelengths of light less than 290 nm, direct excitation of ben- zene in the aquatic or atmospheric environment is unlikely unless a substantial wavelength shift is caused by the media.	-	-	Low .
Oxidation [*]	Direct oxidation of benzene in environ- mental waters is unlikely. Smog chamber data, however, indi- cate that benzene is photooxidized at a rapid rate in the atmo- sphere.	.5x10 ⁻¹⁰	20 to 50 hou 2.4 to 24 h 1 t† mol sec	Medium rs ^{**} ours [†]
Hydrolysis	Probably not a significant fate process.	-	-	Medium
Volatilization	Probably the primary trans port process.		4.81 hours	§ Medium
Sorption	No specific information. The log P value for benzene indicates that sorption may occur.	-	-	Low
Bioaccumulation	The log P value of benzene indicates a low bioaccumulation potential for benzene.	,	-	Low
Biotransformation/ Biodegradation	Benzene can be utilized as the sole source of carbon by several microorganisms and is probably biode- gradable at a slow rate.	-	-	Medium

:

TABLE 17 (concluded)

- * The predominant environmental process which is thought to determine the fate of the compound.
- ** This half-life is calculated from the half-conversion time for benzene based on smog chamber data by Altshuller <u>et al.</u> (1962) and the table of relative reactivities given by Laity et al. (1973).
- † This half-life is the estimated half-life value proposed by Darnall et al. (1976) and is based on the assumption that benzene depletion is due solely to attack by hydroxyl radical.
- †† This second-order rate of reaction of benzene with hydroxyl radicals has been obtained by Darnall et al. (1976) by averaging rates from smog chamber data by Hansen et al. (1975) and Davis et al. (1975).
- S This is the half-life estimated by Mackay and Leinonen (1975) for volatilizaton of benzene from a water column one meter thick at 25°C. This rate of volatilization varies with the environmental situation encountered.

:

TABLE 18

SUMMARY OF AQUATIC FATE OF BENZO[a]ANTHRACENE

Environmental Process	Summary Statement	Rate	Half-Life (^t i/2)	Confidence of Data
Photolysis	Dissolved portion may undergo rapid photo- lysis.		10-50 hrs	Medium ,
Oxidation	Oxidation of PAH by RO ₂ radicals is slow; not a signifi- cant process.	5x10 ³ m sec	38 hrs	Medium
Rydrolysis	PAHs do not contain groups amenable to hydrolysis.	0	-	High
Volatilization	Is probably not as important as adsorp- tion as a transport process.	8x10 ³ hr ⁻¹	90 hrs	Medium
Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement in sediment is considered an important transport process.	Kp≕26,200	-	Medium
Bioaccumulation	A short-term process; PAHs with 4 or less aromatic rings are readily metabolized and long-term parti- tioning into biota is not a significant fate process.	-	- -	Low
Biotransformation/ Biodegradation	PAHs with 4 or less aromatic rings are degraded by microbes and are readily meta- bolized by multicellula organisms; biodegradatic is probably the ultimate fate process.	r on e	-	Low

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

••

٨

SUMMARY OF AQUATIC FATE OF BENZO[ghi]PERYLENE

Environmental Process	Summary Statement**	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis	Dissolved portion may undergo rapid photolysis.		·	
Oxidation	Oxidation of PAH by RO ₂ • radical is slow; not a significant process.			
Hydrolysis	PAHs do not contain groups amenable to hydrolysis.			
Volatilization	Is probably not as important as adsorption as a transport process.			4
Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement in sediment considered the most important transport process.			
Bioaccumulation	A short-term process; PAH's are metabolized slowly and long-term partitioning into biota is not a significant fate process.			
Biotransformation/ Biodegradation	PAHs with 4 or more aromatic rings are degraded slowly by microbes and are readily metabolized by multi-cellular organisms; bio- degradation is probably the ulti- mate fate process.	,		

•

TABLE 20

Environmental Process*	Summary Statement	Rate	Half-Life ((^t 1/2)	Confidence of Data	
Photolysis	Dissolved portion may undergo rapid photolysis.	2.8x10 ⁻⁴ sec ⁻¹ hrs.	1-2	Medium	
Oxidation	Oxidation of PAH by RO2 radicals is slow; not a signi- ficant process.	$\frac{1.68 \times 10^3}{\text{m sec}}$	96 hrs.	Medium	
Hydrolysis	PAHs do not contain groups amenable to hydrolysis.	0	-	High	,
Volatilization	Is probably not as important as adsorp- tion as a transport process.	3x10 ² hr ⁻¹	22 hrs	Medium	
Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement in sediment is considered to be the most impor- tant transport process.	150,000	-	Medium	
Bioaccumulation	A short-term proces; PAHs with 4 or more aromatic rings are slowly metabolized and long-term partitioning into biota is not a significant fate pro- cess.		-	Medium	•
Biotransformation/ Biodegradation	PAHs with 4 or more aromatic rings are slowly degraded by microbes and are slowly metabolized by multicellular organisms; biodegrada- tion is probably the ultimate fate process.	0.2-0.9 mol mg	bacteria protein	al Medium	

SUMMARY OF AQUATIC FATE OF BENZO [a]PYRENE

* There is sufficient information in the reviewed literature to permit assessment of a most probable fate.

.

TABLE 21

SUMMARY OF AQUATIC FATE OF CHRYSENE

Environmental Process*	Summary Statement**	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis	Dissolved portion may undergo rapid phot <u>o</u> lysis.	-	^т ф	
Oxidation	Oxidation of PAH by RO ₂ • radical is slow; not a significant process.			
Hydrolysis	PAHs do not contain groups amenable to hydrolysis.			
Volatilization	Is probably not as important as adsorption as a transport process.			•
Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement in sediment is considered to be an impor- tant transport process.		•	
Bioaccumulation	A short-term process; PAHs with 4 or fewer aromatic rings are readily meta- bolized and long-term par- titioning into biota is not a significant fate process.		-	•
Biotransformation/ Biodegradation	PAHs with 4 or fewer aromatic rings are degraded by microbe and are readily metabolized b multicellular organisms; bio- degradation is probably the ultimate fate process.	2 25 97 -	•	

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

÷

** Very little environmental fate data specific to chrysene were found; the summary statement is made from data reviewed for polynuclear aromatic hydrocarbons.

† Data on chrysene are not sufficient to permit confidence ranking. The confidence of the data reviewed for polynuclear aromatic hydrocarbons in general ranges from low to high.

:

SUMMARY OF AQUATIC FATE OF DIMETHYLNITROSOMINE

с. I

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis [*]	Slow photolysis appears to be the only fate process of any consequence.	-	<u> </u>	Medium .
Oxidation	Probably not important.	-		Low .
Hydrolysis	Probably not important.	- ,	-	Low
Volatilization	Probably not important.	-	_ [:]	Low
Scrption	Probably not important	-	-	Low
Bioaccumulation	Probably not important		. –	Low
Biotransformation/ Biodegradation	Slow degradation is reported to occur in sewage and soil, but this pollutant appears to be resistant to biodegradation in surface waters.	-	-	Medium

* The predominant environmental process which is thought to determine the fate of the compound.

.

. .

A-25

÷

SUMMARY OF AQUATIC FATE OF 2,4-DIMETHYLPHENOL

Environmental Process*	Summary Statement	Rate	Half-Life _(^t 1/2)	Confidence of_Data
Photolysis	Photooxidation may be an important degradative pro- cess in aerated clear sur- face waters.	-	2	Low
Oxidation	Metal-catalyzed oxidation may be relevant in some aerated surface waters.	-		Low
Hydrolysis	Not a relevant environmental process.	. –	-	High
Volatilization	Not a significant process in the aquatic environment.	-	-	Low -
Sorption	Probably not a significant process in the aquatic environment.	-	-	Low
Bioaccumulation	Probably not a significant process in the aquatic environment.	-	-	Low
Biotransformation/ Biodegradation	Available information is inconclusive with regard to degradation in natural surface waters.	-	· –	Low

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

.

.

۰.

.

.

•

ч

SUMMARY OF AQUATIC FATE OF DIPHENYLNITROSAMINE

	Environmențal Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data
	Photolysis	Photolysis may be an important fate process.	-	-	Low
	Oxidation	Probably not important.	· _ ·	-	. Low
	Hydrolysis	Probably not important.		-	Low
	Volatilization	Probably not important.	-		Low
:	Sorption .	No specific data found; may have significance.		-	Low
	Bioaccumulation	No specific data found; importance difficult to assess.	-	-	Low
	Biotransformation/	Diphenylnitrosamine is both more easily degraded and synthesized than dialkyl- nitrosomines.	·	• _	Low
			÷		

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

: •

SUMMARY OF AQUATIC FATE OF DI-N-PROPYLNITROSAMINE

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence
Photolysis [*]	Slow photolysis appears to be the only fate process of any con- sequence.	-	. .	Medium
Oxidation	Probably not important.	-	_	Low
Hydrolysis '	Probably not important.	-	-	Low
Volatilization	Probably not important.	-	-	Low
Sorption	Probably not important.	-		Low
Bioaccumulation	Probably not important.	· _ ·		Low
Biotransformation/ Biodegradation	Slow degradation is reported to occur in sewage and soil, but this pollutant appears to be resistant to bio- degration in surface waters.	-	-	 Medium

The predominent environmental process which is thought to determine the fate of the compound. * .

÷

:

.

SUMMARY OF AQUATIC FATE OF ETHYLBENZENE

í.

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data	
Photolysis	Direct photolytic cleavage is energetically improbable in the troposphere.		-	Low	•
Oxidation [*]	Probably not important as an aquatic fate; however, atmosphereic photooxidation is probably the main fate process.	-	15 hr.	Low	
Hydrolysis	Not aquatically significant. ار	. –	_	High	
Volatilization	Significant transport process responsible for removal of ethylbenzene from water.		5-6 hr.	Low	
Sorption .	Relative importance cannot be determined.	-		Low	
Bioaccumulation	Probably not important.	-	<u> </u>	Low	
Biotransformation/ Biodegradation	Relative importance cannot be determined.	-	-	Low	:

* The predominant environmental process which is thought to determine the fate of the compound.

TABLE 27

SUMMARY OF AQUATIC FATE OF FLUORENE

	Environmental Process	Summary Statement**	Rate	Half-Life (^t 1/2)	Confidence of Data ^T
•	Photolysis	Dissolved portion may undergo photolysis.			
	Oxidation	Oxidation of PAH, by RO ₂ radical is a slow process: not a signi- ficant process.		1	
	Hydrolysis	PAHs do not contain grous amenable to hydrolysis.			
•	Volatilization	Is probably not as important a transport process as adsorption.			• .
	Sorption ^{††}	Measured adsorption coeffi- cients for PAH suspended solids are high; movement v sediment is considered an important transport process for PAH.	ia		
	Bioaccumulation	A short-term process; PAHs with less then 4 rings are readily metabolized and long term partitioning into biota is not a significant fate process.	g- a	•• -	
	Biotransformation/ Biodegradation	PAHs with less than 4 rings are degraded by microbes and are readily metabolized by multicellular organisms; biodegradation is probably the ultimate fate process.	1	•	

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

TABLE 27 (concluded)

- ** Very little environmental fate data specific to fluorene were found; the summary statement is made from data reviewed for PAHs as a group.
- † Data on fluorene are not sufficient to permit confidence ranking. The confidence of the data reviewed for PAHs in general ranges from low to high.
- †† Because the solubility of this compound is relatively high, 50 percent or more may exist in true solution under conditions of normal sediment loading (Southworth 1979).

SUMMARY OF AQUATIC FATE OF NAPHTHALENE

Environmental Process*	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence, of Data
Photolysis	Dissolved portion may undergo rapid photolysis.	_	-	Medium
Oxidation	Oxidation of naphthalene by RO ₂ radical is slow; not a significant process.	-	_	Medium
Hydrolysis 🕠	Naphthalene does not contain groups amenable to hydrolysis.	. –		HÍgh
Volatilization	Role is unknown; could be competitive with adsorp- tion under highly stirred conditions.	-	-	Low
Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement via sedi- ment is considered an important process for PAH.	 :	- ·.	Medium
Bioaccumulation	A short-term process; naphthalene is readily metabolized and long- term partitioning into biota is not a significant fate process.		- 	High
Biotransformation/ Biodegradation	Naphthalene is degraded by microbes and readily metabolized by multi- cellular organisms; biodegradation is probably the ultimate fate process.	0.04-3	l day g day	Medium

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate

.

•

TABLE 29

SUMMARY OF AQUATIC FATE OF PHENANTHRENE

	Environmental Process*	Summary Statement**	Rate	Half-Life (^t 1/2)	Confidence of Data
•	Photolysis	Dissolved portion - may undergo rapid photolysis.	-	-	. 2
	Oxidation	Oxidation of PAR by RO ₂ radical is slow; not a significant process.	0.1 liter mol sec	8x10 ⁶ days	Medium
	Hydrolysis	PAHs do not contain groups amenable to hydrolysis.	-	-	. ~ .
	Volatilization	Is probably not - as important as adsorption as a transport process.	-	-	
	Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement via sediment is considered to be an important transport process.	• • -	-	• -
ч. К	Bloaccumulation	A short-term process; PAHs with 4 or less aromatic rings are readily metabolized and long-term par- titioning into biota is not a significant fate process.	- . • .	-	
	Biotransformation/ Biodegradation	PAHs with 4 or less aromatic rings are degraded by microbes and are readily metabolized by multi- cellular organisms; biodegradation is probably the ultimate fate process.	-	-	

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

- ** Very little environment fate data specific to phenanthrene were found; the summary statement is made from data reviewed for PAHs as a group.
- † Data on phenanthrene are not sufficient to permit confidence ranking in most cases. The confidence of the data reviewed for PAHs in general ranges from low to high.

ſ,

SUMMARY OF AQUATIC FATE OF PHENOL

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis [*]	Photooxidation may be an important degradative process in aerated clear surface waters.	-	·_	Medium
Oxidation*	Metal-catalyzed oxidation may be relevant in some aerated surface waters.	-	-	Medium
Hydrolysis	Not a relevant environmental process.	-	-	High
Volatilization	There is a possibility of some phenol passing into the atmosphere.	-	-	Medium
Sorption	Not a significant process in the aquatic environment.	-	. –	Medium
Bioaccumulation	Not a significant process in the aquatic environment.	-		Medium
Biotransformation/ Biodegradation*	A very significant fate pathway in aqueous media with a sufficient concen- tration of microorganisms.	-	-	High

* Photooxidation, metal-catalyzed oxidation and biodegradation are all probably relevant destructive fate pathways. 14

٠.

2

A--35

SUMMARY	OF	AOUATIC	FATE	OF	PYRENE
---------	----	---------	------	----	--------

Environmental Process	Summary Statement	Rate	Half-Life (^t 1/2)	Confidence of Data
Photolysis	Dissolved portion may undergo rapid photolysis.	-	-	
Oxidation	Oxidation of PAH by RO ₂ • radical is slow; not a significant process.		1,000 days	
; Hydrolysis	PAHs do not contain groups amenable to hydrolysis.	-	-	¢
Volatilization	Is probably not as - important as adsorp- tion as a transport process.	-		-
Sorption	Measured adsorption coefficients for PAH and suspended solids are high; movement in suspended sediment is considered an important transport process.	-	-	
Bioaccumulation.	A short-term process; PAHs with 4 or less aromatic rings are readily metabolized and long-term partitioning into biota is not a significant fate process.	-		
Biotransformation/	PAHs with 4 or fewer aromatic rings are degraded by microbes and are readily meta- bolized by multi- cellular organisms; biodegradation is probably the ultimate fate process.	-	-	

* There is insufficient information in the reviewed literature to permit assessment of a most probable fate.

÷...

- ** Very little environmental fate data specific to pyrene were found; the summary statement is made from data reviewed for PAHs as a group.
- † Data on pyrene are not sufficient to permit confidence ranking. The confidence of the data reviewed for PAHs in general ranges from low to high.

SUMMARY OF AQUATIC FATE OF TOLUENE

Environmental Process	Summary Statement	Rate	Half-Life <u>'(^t1/2)</u>	Confidence of Data
Photolysis	Direct photolytic cleavage is energetically improb- able in the troposphere.	-	-	Medium
Oxidation [*]	Probably not important as an aquatic fate; however, atmospheric photooxidation subordinates all other fate processes.		15 hrs	• Medium
Hydrolysis	Not aquatically significant	: –	- ·	High
Volatilization	Significant transport (process responsible for removal of toluene from water.).193 hr ⁻¹	5.18 hrs.	• Medium
Sorption	Relative importance cannot be determined.	<u> </u>	-	Low
Bioaccumulation	Probably not important.		-	Low
Biotransformation/ Biodegradation	Relative importance cannot be determined.	-	-	Low

* The predominant environmental process which is thought to determine the fate of the compound.

...

3

A-36

TABLE 19 (concluded)

- * There is insufficient information in the reviewed literature to permit assessment of a most probable fate.
- ** Very little environmental fate data specific to benzo[g,h,i]perylene were found; the summary statement is made from data reviewed for PAHs as a group.
- Data on benzo[g,h,i]perylene are not sufficient to permit confidence ranking. The confidence of the data reviewed for PAHs in general ranges from low to high.

1.

A-22