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Biological Removal of Organic Constituents in Quench Water from a Slagging, Fixed-Bed Coal-Gasification Pilot Plant

V. C. Stamoudis and R. G. Luthy

ARGONNE NATIONAL LABORATORY
Energy and Environmental Systems Division

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BIOLOGICAL REMOVAL OF ORGANIC CONSTITUENTS
IN QUENCH WATER FROM A SLAGGING, FIXED-BED
COAL-GASIFICATION PILOT PLANT

by

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Energy and Environmental Systems Division
Pollutant Analysis and Geochemistry Section

February 1980

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BIOLOGICAL REMOVAL OF ORGANIC CONSTITUENTS IN
QUENCH WATER FROM A SLAGGING, FIXED-BED
COAL-GASIFICATION PILOT PLANT

by

Vassilis C. Stamoudis and Richard G. Luthy

ABSTRACT

This study is part of an effort to assess the efficiency of activated-sludge treatment for removal of organic constituents from high-Btu coal-gasification pilot-plant quench waters. A sample of raw-gas quench water was obtained from the Grand Forks Energy and Technology Center's pilot plant, which employs the slagging, fixed-bed gasification process. The quench water generated in the processing of Indian Head lignite was pre-treated to reduce ammonia and alkalinity, and then diluted and subjected to long-term biological treatment, followed by detailed characterization and analysis of organic constituents.

The pretreated (influent) and treated (effluent) samples were extracted using a methylene chloride, pH-fractionation method to obtain acid, base, and neutral fractions, which were analyzed by capillary-column gas chromatography/mass spectrometry (GC/MS). Over 99% of the total extractable and chromatographable organic material in the influent acid fraction was composed of phenol and alkylated phenols. Biological treatment removed these compounds almost completely. Major components of the influent base fraction were alkylated pyridines, anilines, aminopyrroles, imidazoles and/or pyrazoles, diazines, and quinolines. Removal efficiency of these compounds ranged between 90 and 100%. The influent neutral fraction was composed mainly of cycloalkanes, cycloalkenes, naphthalene, indole, acetophenone, and benzonitrile. Alkylated benzenes were generally absent. Removal efficiencies of these compounds were generally very good, except for certain alkylated cycloalkanes and cycloalkenes. Results are compared with those of a similar study on HYGAS coal-gasification quench water.

1 INTRODUCTION

This study is a continuation of a cooperative program between Argonne National Laboratory (ANL) and Carnegie-Mellon University (C-MU), conducted with the assistance of the Institute of Gas Technology (IGT) and Grand Forks Energy and Technology Center (GFETC). The objectives of these studies are to characterize process effluents and to evaluate the efficiency of biological treatment for removal of organic constituents present in quench waters from high-Btu coal-gasification pilot plants.

A study of biological treatment for removal of organic contaminants in quench waters from the IGT HYGAS coal-gasification pilot plant has been completed and published by ANL (Stamoudis et al., 1979). The results of that

study showed activated-sludge treatment effectively removed the majority of organic constituents with the exception of certain constituents in the base and neutral fractions. The sample chosen for the present investigation was a quench water from the GFETC slagging, fixed-bed (SFB) coal-gasification pilot plant. One objective of the present study was to compare composition and component removal efficiencies of HYGAS and SFB process condensates. These pilot-plant quench waters, while not strictly representative of wastewaters that would be expected in a demonstration or commercial scale HYGAS or SFB coal-gasification plant, provide useful information to evaluate the efficiency of biological oxidation for removal of organic constituents.

HYGAS and SFB process condensates have been chosen for these investigations because: (1) these processes are representative of major Department of Energy-sponsored coal-gasification systems in an advanced state of development, (2) the processes produce process waters contaminated with organic pollutants, and (3) the basic biological treatability characteristics of these waters have been the subject of recent experimental investigations (Luthy and Tallon, 1978; Luthy et al., 1979).

A literature review has revealed that only limited information exists on characterization and removal of organic contaminants in coal-gasification condensates. Singer et al. (1978 and 1979) have summarized available characterization data and have initiated preliminary biological treatability studies on synthetic mixtures. Additional characterization data are provided by White and Schmidt (1978) on volatile, polar organics in by-product waters from two gasification processes, SYNTHANE and SFB. Dark (1979) has presented results of analysis of aromatic hydrocarbons in biologically treated process water from an unspecified coal-gasification process.

2 FIELD AND LABORATORY PROCEDURES

A description of the GFETC-SFB pilot-plant effluent flow-distributions and pilot-plant test program is provided by Ellman et al. (1979). Test conditions for the pilot-plant run from which quench waters were obtained are also described. Procedures employed for handling and processing of raw quench water are detailed by Luthy, Sekel, and Tallon (1979). These procedures are summarized below.

2.1 QUENCH WATER SELECTION, COLLECTION, AND STORAGE

The water used in this study was GFETC-SFB coal-gasification raw-gas quench water generated during gasifier run RA-52 using Indian Head lignite. Approximately 250 gal of decanted quench water was shipped to C-MU from GFETC via freezer truck. Raw quench water was shipped and stored in 5-gal plastic containers. Since it was necessary to provide means for long-term storage of raw quench water, the samples were preserved by freezing until needed as feed for the biological reactors. Although no studies were performed to assess the stability of trace organics in frozen samples, a recent study regarding the stability of HYGAS quench waters suggests that the extractable/chromatographable components are stable up to at least 60 days under refrigeration (Raphaelian and Harrison, 1979).

2.2 QUENCH WATER PRETREATMENT

Representative raw quench water characteristics for the samples used are given in Table 2.1. The quench water was pretreated to reduce excess alkalinity and ammonia concentrations by lime addition and air stripping. This pretreatment simulated ammonia removal as may be utilized in a commercial treatment train. It was found that ammonia-stripped quench water could not be processed through a biological reactor at full strength. However, a series of sequential and parallel tests with stripped SFB effluent in which feed strength and loading were varied independently demonstrated that stable biological reactor performance could be achieved by diluting ammonia-stripped quench water to 33% strength.

2.3 BIOLOGICAL TREATMENT

The biological reactor employed in this study was a complete-mix, single-stage, air-activated sludge reactor with an internal clarifier. This reactor was operated under conditions whereby hydraulic residence time, mean bacterial-cell residence time, and feed strength were held as experimental constants. Dependent variables were steady-state values of mixed-liquor volatile suspended solids (MLVSS) and effluent substrate concentration. The biological reactor was acclimatized to the quench water over a period of time such that the reactor was subjected to three complete bacterial sludge wasting cycles prior to the collection of steady-state performance data. The reactor was then operated for seven weeks during which two-week composite samples were collected for trace-organic analysis. The composite samples were collected in glass containers and shipped immediately to Argonne National Laboratory, where they were refrigerated prior to extraction.

2.4 EXTRACTION PROCEDURES AND GC/MS ANALYSIS

The extraction scheme used is presented in Fig. 2.1. This scheme employs pH-fractionation into acid, base, and neutral fractions, and follows generally accepted protocols. Details of the extraction scheme are given in Stamoudis et al. (1979). One liter of influent and 4 L of effluent were extracted with methylene chloride. Emulsion problems during extraction were minimized by successive freezing and thawing.

GC/MS analysis of organic constituents was performed as described in Stamoudis et al. (1979). Compound identifications were based on mass spectra and known retention times. Percentage removal of compounds was estimated by comparison of total-ion chromatograms of influent and effluent. This method assumes that the concentration levels of compounds were in the optimum range of linearity with respect to total-ion (or single-ion) areas as a function of concentration, and that extraction yields for compounds in the influent and effluent were the same.

Extraction efficiency was evaluated by extracting a standard mixture in distilled water containing acid, base, and neutral organic compounds. Results of percent recovery of 16 organic compounds are given in Table 2.2. Average recovery for the 16 compounds was 84%.

Ten organic compounds were used as models to develop total-ion (or single-ion) areas as a function of concentration relationships for estimation

Table 2.1 Representative Raw Quench Water Characteristics during Biological Oxidation Studies

Parameter ^a	SFB ^{b,c} (Run RA-52)
COD	25,400
Phenolics	5,100
NH ₃ -N	5,200
NO ₃	<2
Organic-N	90
CN ⁻ _{tot}	12
SCN	140
S ²⁻	150
SO ₄ ²⁻	150
P	13
Alkalinity (as CaCO ₃)	18,400
Total Acidity (as CaCO ₃)	24,000
Total Oil & Grease	300
Soluble Oil & Grease	190
Conductivity (μmhos/cm)	20,000
pH (units)	8.4

^aAll units in mg/L except as noted.

^bSFB data from Luthy, Sekel and Tallon (1979).

^cDouble-decanted gasifier quench condensate.

Fig. 2.1 Extraction Scheme for Biological Reactor Influent and Effluent Samples

Table 2.2 Percent Recoveries of Organics
Extracted from Spiked Distilled
Water Based on GC Analysis

Compound	% Recovery
o-Xylene	65 ^a
Mesitylene	65
3-Octanone	85
1-Heptanol	86
n-Butylbenzene	56
Trimethylpyridine	54
Phenol	82 ^a
o-Cresol	95 ^a
o-Ethylphenol	105
Napthalene	68
Dimethylnapthalene	91
Anthracene	99
d ₁₀ -Anthracene	102
Acridine	78 ^b
Carbazole	101
Pyrene	105
Average for 16 compounds	84%

^a Average of two separate analyses.

^b 52% recovered in neutral and 25% in base fraction.

of concentration levels of organic constituents. These compounds were phenol, cresol, xylene, trimethylpyridine, ethylphenol, naphthalene, anthracene, acridine, carbazole, and benzonitrile. Benzonitrile was studied more thoroughly and the results were published (Stamoudis et al., 1979).

3 EXPERIMENTAL RESULTS

3.1 BIOLOGICAL REACTOR CHARACTERISTICS

Table 3.1 summarizes general operating parameters and performance characteristics for the biological reactor employed for evaluation of the removal efficiencies of organic constituents. Data in Table 3.1 show that the biological reactor was managed with a mean bacterial-cell residence time of 15 days and a hydraulic residence time of 2 days. This practice resulted in a steady-state concentration of MLVSS of 1500 mg/L and a COD removal rate of 0.37 mg COD removal/mg MLVSS-day. There was approximately 81% removal of COD and over 99.9% removal of phenolics as determined by the 4-aminoantipyrine colorimetric procedure. As shown below (Section 4.1), GC/MS analysis of composite effluent samples gave a lower average effluent concentration for specific phenolic compounds than was measured by the colorimetric procedure. The biological reactor demonstrated that a high degree of nitrification was achieved. Approximately 78% of available nitrogen in influent was nitrified.

3.2 REMOVAL EFFICIENCY OF ORGANIC CONSTITUENTS

Total-ion chromatograms of the acid, base, and neutral fractions of the biological reactor influent and effluent are presented in Figs. 3.1-3.3. Visual comparisons reveal that activated-sludge treatment removed the bulk of the organic constituents.

Estimated influent and effluent concentrations and removal percentages of major extractable and chromatographable organic compounds identified in the acid, base, and neutral fractions are presented in Tables 3.2-3.4. Because concentrations were estimated on the basis of total-ion counts referenced to several standard compounds, and because of possible losses due to extraction and separation procedures, it is believed that reported concentration levels are only semiquantitative estimates (± 33 -50%). Percentage removal values are considered to be more accurate than concentration values, because these estimates are based on relative total-ion counts for the same compound (assuming similar extraction efficiencies for the compound in the reactor influent and effluent).

4 DISCUSSION

4.1 ACID FRACTIONS

As shown in Table 3.2 the acid fraction of the quench water influent consisted almost exclusively of phenol and single-ring alkylated phenolic compounds. Phenol and cresols constitute the largest fraction of observed organics. The acid influent fraction represented more than 99.3% of the total identified organics on a mass basis. Despite the abundance of these

Table 3.1 Average Biological Reactor Performance Data
for Evaluation of Removal of Trace Organic
Compounds

Parameter ^a	SFB ^b Quench Water	
Mean Cell Residence Time, days	15	
Hydraulic Residence Time, days	9.2	
COD Removal Rate, days ⁻¹	0.37	
Mixed Liquor Suspended Solids, MLSS	1870	
Mixed Liquor Volatile Sus. Solids, MLVSS	1500	
O ₂ Util. Rate, mg O ₂ /mg MLVSS-day	0.33	
Zone Settling Velocity, ft/hr	15	
Sludge Volume Index, mL/g MLSS	39	
	<u>Inf</u>	<u>Eff</u>
COD	6780	1260
Phenolics	1510	1
NH ₃ -N	157	17
NO ₃ -N	<2	160
Org-N	43	21
CN ⁻ _{tot}	0.5	0.9
SCN ⁻	16	2
S ²⁻	4	<3
Suspended Oil and Grease	<10	<10
Alkalinity (as CaCO ₃)	1240	560
Conductivity (μmhos/cm)	3740	4520

^aAll units in mg/L except as noted.

^b33% strength ammonia stripped wastewater. Data source:
Luthy, Sekel and Tallon (1979).

Fig. 3.1 Total-Ion Chromatograms of Influent and Effluent Acid-Fraction Extracts of Biologically Treated GFETC Slagging Fixed-Bed Coal-Gasification Quench Water

Fig. 3.2 Total-Ion Chromatograms of Influent and Effluent Base-Fraction Extracts of Biologically Treated GFETC Slagging Fixed-Bed Coal-Gasification Quench Water

Fig. 3.3 Total-Ion Chromatograms of Influent and Effluent Neutral-Fraction Extracts of Biologically Treated GFETC Slagging Fixed-Bed Coal-Gasification Quench Water

Table 3.2 Concentration in Biological Reactor Influent and Effluent and Percent Removal of Acid-Fraction Organics in GFETC Slagging, Fixed-Bed Coal-Gasification Quench Water

Peak No.	Compound Name	Estimated Influent Conc. (µg/L) ^a	Estimated Effluent Conc. (µg/L) ^b	Estimated Percent Removal
5	Dichlorobenzene	NT	8	++
10	Phenol	>500,000	60	99.99
14 & 16	Cresols	30,000	12	99.96
18	Methoxyphenol	ND	NT	100
20	Cresol	>150,000	45	99.97
27	Methyl-methoxyphenol	50	trace	100
28	Ethylphenol	870	4	99.54
30 & 31	Dimethylphenols	4,500	trace	100
32	Methyl-methoxyphenol	1,700	NT	100
38 & 40	C ₂ -Phenols	12,500	7	99.94
50	C ₂ -Phenol	2,500	1	99.96
52	C ₃ -Phenol	70	NT	100
55 & 56	C ₃ -Phenols	400	NT	100
58	C ₂ -Methoxyphenol	430	NT	100
62 - 66	C ₃ -Phenols	1,500	NT	100
69	Unknown	ND	5	ND/PR
70	C ₃ -Phenol	150	NT	100
77	C ₃ H ₆ -Phenol or Hydroxyindan	300	NT	100
82	C ₃ H ₆ -Phenol or Hydroxyindan	ND	<1	ND/PR
85	C ₃ H ₆ -Phenol or Hydroxyindan	400	NT	100
90	C ₃ H ₄ -Phenol or Hydroxyindan	120	NT	100
105	C ₄ H ₈ -Phenol or Methyl-hydroxyindan	ND	<1	ND/PR
110	C ₄ -Phenol	ND	<1	ND/PR
125	C ₄ -Phenol	ND	<1	ND/PR
130	Naphthol	ND	<1	ND/PR
220	Plastisizer (phthalate)	NT	<1	++
250	Plastisizer (phthalate)	NT	<1	++

ND, not determinable. NT, not detected. ++, found in effluent only.

ND/PR stands for not-determinable/poorly-removed. Because the effluent contained fewer organics of lower concentration levels, the final extract volume had to be concentrated to a volume much smaller than that of the influent. Certain peaks, corresponding to compounds that were in very low concentration levels in the influent, were then easier to identify in the effluent, but were obscured or in the "noise" level in the influent.

^aUndiluted ammonia-stripped quench water composition reported here.

^bActual biological reactor effluent concentrations were multiplied by 3 as reported here to factor out apparent removal owing to dilution. Thus all SFB effluent concentrations refer to an undiluted basis.

Table 3.3 Concentration in Biological Reactor Influent and Effluent and Percent Removal of Base-Fraction Organics in GFETC Slagging, Fixed-Bed Coal-Gasification Quench Water

Peak No.	Compound Name	Estimated Influent Conc. ^a (µg/L)	Estimated Effluent Conc. ^b (µg/L)	Estimated Percent Removal
4	Methyltetrazole ?	21	20	5
15	Picoline	76	2	97.4
16	Methyldiazine	20	NT	100
30 & 31	Picolines	65	NT	100
34	C ₂ -Imidazole or C ₂ -Pyrazole	ND	3	ND/PR
35	Ethylpyridine	14	NT	100
36	C ₂ -Imidazole or C ₂ -Pyrazole	ND	3.5	ND/PR
38	C ₂ -Diazine	7	2	71
39	Ethylimidazole or Ethylpyrazole	185	10	95
50	C ₂ -Pyridine	16	NT	100
52	C ₃ -Imidazole or C ₃ -Pyrazole	10	0.9	91
55	C ₂ -Pyridine	9	NT	100
62	C ₁ -Aminopyrrole	1,050	5	99.5
72	C ₃ -Imidazole or C ₃ -Pyrazole	64	1	98.5
73	C ₃ -Imidazole or C ₃ -Pyrazole	19	1	95
82	C ₃ -Imidazole or C ₃ -Pyrazole or C ₂ -Aminopyrrole		<1	
90	Aniline	180	10	94.5
94	C ₃ -Imidazole or C ₃ -Pyrazole or C ₂ -Aminopyrrole	270	<0.5	99.8
104	C ₃ -Imidazole or C ₃ -Pyrazole or C ₂ -Aminopyrrole	34	NT	100
105	Methoxyaniline	ND	<1	ND/PR
106	C ₄ -Imidazole or C ₄ -Pyrazole or C ₃ -Aminopyrrole	10	NT	100
110	Methylaniline	58	0.5	99+
112	Methoxyaniline	ND	0.5	ND/PR
116	Methoxyaniline	22	1	95
120	Methylaniline	21	NT	100

Table 3.3 (Contd.)

Peak No.	Compound Name	Estimated Influent Conc. ^a (µg/L)	Estimated Effluent Conc. ^b (µg/L)	Estimated Percent Removal
129	Methoxyaniline	10	1.5	85
135	C ₄ -Pyridine	26	0.4	98.5
175	Quinoline	57	NT	100
180	C ₅ -Pyridine	25	2	92
185	Isoquinoline	6	NT	100
200	Methylquinoline	7	1	83

ND, not determinable. NT, not detected. ND/PR, not determinable/poorly removed, see note under Table 3.2

^aSee note a in Table 3.2.

^bSee note b in Table 3.2.

Table 3.4 Concentration in Biological Reactor Influent and Effluent and Percent Removal of Neutral-Fraction Organics on GFETC Slagging, Fixed-Bed Coal-Gasification Quench Water

Peak No.	Compound Name	Estimated Influent Conc. ^a (µg/L)	Estimated Effluent Conc. ^b (µg/L)	Estimated Percent Removal
3	Toluene	410	50	88
8	Cyclohexane	76	67	12
16	C ₂ -Cyclopentane or Methylcyclohexane	19	2.4	87
18	C ₂ -Cyclopentane or Methylcyclohexane	17	6	65
30	C ₂ -Cyclopentane or Methylcyclohexane	31	4	87
34	Methyl-cyclopentenone	385	42	89
41	C ₃ -Cyclopentene or C ₂ -Cyclohexene	27	16	41
43	C ₃ -Cyclopentene or C ₂ -Cyclohexene	26	5	83
48	Dimethylfuran	204	trace	100
51	C ₄ -Cyclopentene or C ₃ -Cyclohexene	290	33	89 (combined)
52 + 53	Benzonitrile and C ₃ -Cyclopentene or C ₂ -Cyclohexene			
64	C ₃ -Cyclopentene or C ₂ -Cyclohexene			
		57	1.3	98

Table 3.4 (Contd.)

Peak No.	Compound Name	Estimated Influent Conc. ^a (µg/L)	Estimated Effluent Conc. ^b (µg/L)	Estimated Percent Removal
68	C ₃ -Cyclopentene or C ₂ -Cyclohexene	690	trace	100
80	C ₄ -Cyclopentene or C ₃ -Cyclohexene	71	trace	100
85	Acetophenone	43	trace	100
92	C ₄ -Cyclopentene or C ₃ -Cyclohexene	162	1.5	99
100	C ₄ -Cyclopentene or C ₃ -Cyclohexene	48	1.1	98
120	C ₄ -Cyclopentene or C ₃ -Cyclohexene	44	trace	100
131	C ₃ -Cyclopentene or C ₂ -Cyclohexene and C ₄ -Cyclopentene or C ₃ -Cyclohexene	54	trace	100
150	Naphthalene	18	trace	100
152	C ₅ -Benzene	10	2	80
164	C ₅ -Cyclopentadiene or C ₄ -Cyclohexadiene	28	trace	100
168	C ₅ -Cyclopentadiene or C ₄ -Cyclohexadiene	29	trace	100
182	C ₆ -Cyclopentene or C ₅ -Cyclohexene	20	trace	100
194	C ₆ -Cyclopentadiene or C ₅ -Cyclohexadiene and	100	trace	100
195	Indanone			
200	C ₆ -Cyclopentadiene or C ₅ -Cyclohexadiene	29	trace	100
248	Indole	270	2	99.3
420	Unknown	440	trace	100

^aSee note a in Table 3.2.^bSee note b in Table 3.2.

compounds in the influent, only very small amounts of phenol, cresols, and certain higher substituted phenols or hydroxyindans were detected in the effluent. Overall removal efficiency for acid fraction organics was >99.9%. The effluent chromatogram showed a series of small peaks with retention times above 60 min, corresponding to either alkylated phenols or alkylated hydroxyindans with olefinic substitutions. These compounds were not detectable in the influent because influent extract samples could not be analyzed effectively if the extract column was reduced to the small volume used for effluent samples.

4.2 BASE FRACTIONS

Table 3.3 shows that the base influent fraction consisted primarily of a series of nitrogen heterocyclic compounds, including alkylated aminopyrroles, imidazoles and/or pyrazoles, diazines, pyridines, quinolines, indoles, as well as aniline, alkylated anilines, and methoxyanilines. In general, removal efficiencies for these compounds were very good. The overall removal efficiency for base-fraction organics was over 96%. Most of the peaks with retention times above 60 min in the influent and effluent base-fraction chromatograms (Fig. 3.2) were judged to be extraneous, and are attributed to plasticizers.

4.3 NEUTRAL FRACTIONS

As shown in Table 3.4, toluene and alkylated cycloalkanes and cycloalkenes were the dominant components of the influent neutral fraction. The influent also showed cycloalkenones, dimethylfuran, C₅-benzene, benzonitrile, acetophenone, naphthalene, indanone, and indole. The removal of these compounds was generally very good with the exception of certain alkylated cycloalkanes and cycloalkenes. Most of the peaks with retention times above 60 min (Fig. 3.3) were attributed either to plasticizers (Peak Nos. 395 & 650 correspond to phthalates) or to compounds with quite obscure spectra. These peaks may represent biological cellular metabolites, or products resulting from biological degradation. Peak No. 420 also could not be identified with certainty; the mass spectrum had two predominant masses (188 and 94).

5 SUMMARY AND COMPARISON OF RESULTS WITH THE HYGAS STUDY

This study showed that over 99% of the extractable and chromatographable organic material in the biological reactor influent consisted of phenols and alkylated phenols. These compounds were removed almost completely by activated-sludge treatment. These findings were similar to those observed in a previous investigation of HYGAS process water (Stamoudis et al., 1979).

In the HYGAS study it was found that the major components of the base-fraction organics were aniline and alkylated anilines, pyridine and alkylated pyridines, quinolines, and indoles. However, the SFB base fraction, besides the presence of the above compounds, displayed as major components tetrazoles, aminopyrroles, imidazoles and/or pyrazoles, methoxyanilines, and diazines. Despite the marked compositional differences, the biological reactor removal efficiencies were good in both quench waters (overall removal >90% for HYGAS, >96% for SFB).

Organic compounds in the neutral fraction of the SFB biological reactor influent consisted mainly of toluene, benzonitrile, acetophenone, naphthalene, indole, and alkylated cycloalkanes and cycloalkenes. The GFETC neutral fraction sample did not possess the wide range of typical aromatic hydrocarbons observed in the study with HYGAS quench water. In general there were high removal efficiencies for SFB neutral-fraction organics, excepting certain alkylated cycloalkanes. It was observed in the HYGAS study that removal efficiency of neutral-fraction organics was dependent to a certain extent on chemical structure. The lack of a wide variety of aromatic hydrocarbons in SFB biological reactor influent precludes such observations for this process quench water. The variety of alkylated benzenes abundantly present in the HYGAS sample might be attributed to the use of toluene as a medium during the gasification process. Differences between quench water composition of HYGAS and SFB samples are attributable to differences in coal type, gasifier operating conditions, and other process variables.

6 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study it was concluded that over 99% of extractable and chromatographable organic material, on a mass basis, was represented in the acid fraction of process quench water from slagging, fixed-bed coal gasification. The remaining organic material was represented in the basic and neutral fractions, with the former somewhat larger than the latter. Biological treatment removed almost all of the organics in the acid fraction, and over 96% and 93% of the organics in the base and neutral fractions, respectively. Removal efficiencies found in an earlier study of a HYGAS coal-gasification process quench water were very similar, despite marked compositional differences in the base and neutral fractions.

Analytical data presented in the studies mentioned above are at best semiquantitative estimates. In future work it is necessary to evaluate extraction efficiencies for organic compounds from the coal-gasification process effluents, with emphasis on compounds identified as hazardous by biological assays. Though not identified by the GC/MS procedures employed here, recent reverse-phase, high-pressure, liquid chromatographic analysis of GFETC wastewater (Walters and Luthy, 1979) has shown the presence of polynuclear aromatic hydrocarbons. Therefore, it is recommended that special studies be conducted for evaluation of removal efficiencies of polynuclear aromatic hydrocarbons.

It is also recommended that future work evaluate the fate of trace organic compounds during wastewater pretreatment. These studies should simulate quench water pretreatment of solvent extraction and steam stripping.

It is recommended that additional studies be initiated to evaluate the extent to which trace organic compounds are being adsorbed on bacterial flocs rather than being degraded biologically. This work should include extraction of biological sludge in order to attempt mass balances for trace organic compounds. Work should also be initiated to evaluate improved removal efficiencies for trace base- and neutral-fraction organics. This work may include evaluation of powdered activated carbon addition to the biological reactor.

Finally, it is recommended that emphasis in the analysis should be given to various fractions that were tested to be toxic and/or carcinogenic by accepted biological tests.

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