Analysis Of Refinery Wastewaters For The EPA Priority Pollutants

Interim Report

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ANALYSIS OF REFINERY WASTEWATERS FOR THE EPA PRIORITY POLLUTANTS

INTERIM REPORT

Prepared for
American Petroleum Institute
Analytical Systems Task Force (W-22)
Washington, D. C.

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Radian Corporation
8500 Shoal Creek Boulevard
Austin, Texas 78766

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Members: J. D. Hallett(Chairman) - Shell Oil Company
S. C. Blum - Exxon Research and Engineering Company
R. A. Brown* - Exxon Research and Engineering Company
L. J. Duffy - Standard Oil (Indiana)
W. O. Fitzgibbons* - Standard Oil Company of Ohio
U. V. Henderson - Texaco Incorporated
F. P. Hochgesang - Mobil Research and Development Corporation
D. S. Rulison - Standard Oil Company of Ohio
G. H. Stanko - Shell Development Company
F. T. Weiss* - Shell Development Company

* Former members

Statistical Advisors: N. R. Crawford - Texaco Incoporated
J. W. Gorman - Amoco Oil Company

API Staff: J. G. Thatcher
W. M. Ollison

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EXECUTIVE SUMMARY

Intake waters, wastewater feed to biotreatment units, and final effluent streams from 17 petroleum refineries were sampled by the EPA within the past year to screen for the presence or absence of the 129 substances on the EPA Priority Pollutant list. Concurrently, an API contractor and/or various individual petroleum companies sampled nine of the 17 refineries. Analytical results, except for trace elements, are not available at this time for all 17 refineries sampled either from EPA or the petroleum industry.

The following table summarizes analytical results from this study:

	Refinery Intake Waters	Wastewater Feed to Biotreatment	Refinery Final Effluents
ORGANICS			
Total No. Identified			
API	40	45	36
EPA	24	33	18
Combined	44	49	38
Range (ppb)			
API	<1-150	<1-44,000	<1-60
EPA	<1-160*	<1-16,000	<1-35*
Combined	<1-160*	<1-44,000	<1-60*
TRACE ELEMENTS			
Total No. Identified			
API	13	13	13
EPA	11	12	12
Combined	13	13	13
Range (ppb)			
API	<1-1,300	<1-9,600	<1-1,100
EPA	<1-210	<1-4,900	<1-1,000
Combined	<1-1,300	<1-9,600	<1-1,100

*The EPA reported values from 190 to 2,000 ppb for bis(2-ethylhexyl) phthalate among five refineries. These values are extremely suspect. EPA also reported a value of 750 ppb for methylene chloride at one refinery. This value is suspect because of EPA-acknowledged contamination. Therefore these values have been excluded from this table.

In no case were all of the identified pollutants detected in any of the samples from any one refinery. Pollutants detected in samples of feeds to refinery biotreatment systems were significantly reduced, or removed, within the treatment system. Numerous cases occurred where levels of particular pollutants were found to be higher in the refinery's intake than effluent waters.

In addition special analytical studies were conducted by API on refinery final effluents. The studies included spiking experiments, inter-laboratory comparisons and analysis of sample blanks. Results from these investigations indicated that clarification recoveries and precision were extremely variable. Differences in the inter-laboratory data ranged from 0 to 200 percent. Analysis of samples for the PNAs by an alternate technique demonstrated that the EPA analytical protocol was unable to differentiate between certain isomeric species. Many of the samples analyzed were found or were suspected to be contaminated with substances such as methylene chloride and bis(2-ethylhexyl)phthalate. Therefore, the currently applied EPA analytical and sampling protocol was found to be inadequate for the quantification and, in some cases, identification of priority pollutants at the low ppb level.

Although the combined EPA-API data base is limited both in scope and accuracy, it does indicate that many (approximately 65%) of the Priority Pollutants are not present in refinery effluents. In addition, most of the pollutants detected are generally found at extremely low levels and are not uniformly present among refineries sampled nor in replicate samples taken within a single refinery.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Best Practicable Control Technology Currently Available, as utilized by refineries in this study, provides effective removal of Priority Pollutants from refinery wastewaters.
- The Priority Pollutants not detected by any laboratory in any of the samples taken during this study can be eliminated from further consideration in developing BATEA limitations for Priority Pollutants for the refining industry. Numerous other pollutants detected in occasional samples or at low levels in samples may also be eliminated as additional data are obtained.
- The current data base is inadequate to derive specific numerical effluent limitations for individual Priority Pollutants. Only limited data are available to assess analytical and effluent variability. The analytical procedures used to derive the data have not been validated and adequate accuracy and precision data are not available.
- The sampling methodology is inadequate to insure that contamination of samples with substances on the Priority Pollutant list will not occur.
- The variability of the results obtained by two or more laboratories for individual pollutants in replicate samples verifies that individual data points should be viewed in terms of ranges rather than specific values. (Specific values have been used in this report only to give the reader a basis for comparison.)

Recommendations

- Validation of analytical and sampling methods must be carried out. Any effluent limitations proposed for specific Priority Pollutants must be derived from data obtained using validated methods.
- Prior to proposing effluent limitations for any of the Priority Pollutants a more thorough study of refinery wastewaters is necessary. This study should be designed to afford meaningful statistical evaluation and should consider factors presumed to affect effluent quality and variability such as refinery geographic location, crude supply sources, size, complexity, and other appropriate factors to obtain representative sampling.
- Unless appropriate validation programs are completed, Priority Pollutant data must be viewed in terms of ranges rather than as specific values.

1.0 INTRODUCTION

In late 1976, the United States Environmental Protection Agency (EPA) commenced a two-phase program designed to determine the concentrations of 129 inorganic and organic Priority Pollutants (Table 1-1) in the wastewaters from industrial facilities contained in 21 broad categories. Phase I of the program consisted of a screening study aimed at defining the approximate concentrations of the Priority Pollutants in effluents. Under Phase II, the EPA intended to conduct a verification study designed to confirm the concentrations of the Priority Pollutants in effluents. Under Phase II, the EPA proposes to use the information derived from this screening study to provide a data base necessary for the development of Priority Pollutant limitations. No verification study has been announced.

The petroleum refining industry was included in the EPA Priority Pollutants study. Therefore, the American Petroleum Institute (API) formed an Analytical Systems Task Force (W-22) to conduct an independent program that would parallel the EPA screening study. In Phase I, the R.S. Kerr Laboratories (RSKERL) of the EPA collected samples from 12 refineries. An additional five refineries were later included and were sampled by Ryckman, Edgerly, Tomlinson and Associates (RETA) and Burns and Roe personnel. The objectives of the API program included the development of an independent Priority Pollutants data base and the evaluation of sampling and analytical procedures employed by the EPA. In order to provide the needed support for the study, the API contracted with Radian Corporation and Exxon Research and Engineering Company (Exxon R & E). The sampling effort was conducted by Exxon R & E and API member companies, while the analytical support was provided by Radian, Exxon R & E and various API member companies and independent contractors.

TABLE 1-1. PRIORITY POLLUTANTS

	Compound Name
1.	*Acenaphthene
2.	*Acrolein
3.	*Acrylonitrile
4.	*Benzene
5.	*Benzidene
6.	*Carbon tetrachloride (Tetrachloromethane)
	*Chlorinated benzenes (other than dichlorobenzenes)
7.	Chlorobenzene
8.	1,2,4-Trichlorobenzene
9.	Hexachlorobenzene
	*Chlorinated ethanes (including 1,2-Dichloroethane, 1,1,1-Trichloroethane and Hexachloroethane)
10.	1,2-Dichloroethane
11.	1,1,1-Trichloroethane
12.	Hexachloroethane
13.	1,1-Dichloroethane
14.	1,1,2-Trichloroethane
15.	1,1,2,2-Tetrachloroethane
16.	Chloroethane
	*Chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)
17.	bis(Chloromethyl) ether
18.	bis(2-Chloroethyl) ether
19.	2-Chloroethyl vinyl ether (mixed)
	*Chlorinated naphthalene
20.	2-Chloronaphthalene
	*Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
21.	2,4,6-Trichlorophenol
22.	Parachlorometa cresol
23.	*Chloroform (Trichloromethane)
24.	*2-Chlorophenol
	*Dichlorobenzenes
25.	1,2-Dichlorobenzene
26.	1,3-Dichlorobenzene
27.	1,4-Dichlorobenzene
	*Dichlorobenzidine
28.	3,3'-Dichlorobenzidine
	*Dichloroethylenes (1,1-Dichloroethylene and 1,2-Dichloroethylene)
29.	1,1-Dichloroethylene
30.	1,2-trans-Dichloroethylene

Table 1-1 continued

31. *2,4-Dichlorophenol
*Dichloropropane and Dichloropropene
32. 1,2-Dichloropropane
33. 1,2-Dichloropropylene (1,3-Dichloropropene)
34. *2,4-Dimethylphenol
*Dinitrotoluenes
35. 2,4-Dinitrotoluene
36. 2,6-Dinitrotoluene
37. *1,2-Diphenylhydrazine
38. *Ethylbenzene
39. *Fluoranthene
*Haloethers (other than those listed elsewhere)
40. 4-Chlorophenyl phenyl ether
41. 4-Bromophenyl phenyl ether
42. bis(2-Chloroisopropyl) ether
43. bis(2-Chloroethoxy) methane
*Halomethanes (other than those listed elsewhere)
44. Methylene chloride (Dichloromethane)
45. Methyl chloride (Chloromethane)
46. Methyl bromide (Bromomethane)
47. Bromoform (Tribromomethane)
48. Dichlorobromomethane
49. Trichlorofluoromethane
50. Dichlorodifluoromethane
51. Chlorodibromomethane
52. *Hexachlorobutadiene
53. *Hexachlorocyclopentadiene
54. *Isophorone
55. *Naphthalene
56. *Nitrobenzene
*Nitrophenols (including 2,4-Dinitrophenol and Dinitrocresol)
57. 2-Nitrophenol
58. 4-Nitrophenol
59. *2,4-Dinitrophenol
60. 4,6-Dinitro-o-cresol
*Nitrosoamines
61. N-Nitrosodimethylamine
62. N-Nitrosodiphenylamine
63. N-Nitrosodi-n-propylamine
64. *Pentachlorophenol
65. *Phenol
*Phthalate esters
66. bis(2-Ethylhexyl) phthalate
67. Butyl benzyl phthalate
68. Di-n-butyl phthalate
69. Di-n-octyl phthalate[1]
70. Diethyl phthalate
71. Dimethyl phthalate

Table 1-1 continued

*Polynuclear aromatic hydrocarbons

72. Benzo(a)anthracene (1,2-Benzanthracene)
73. Benzo(a)pyrene (3,4-Benzopyrene)
74. Benzo(b)fluoranthene (3,4-Benzofluoranthene)
75. Benzo(k)fluoranthene (11,12-Benzofluoranthene)
76. Chrysene
77. Acenaphthylene
78. Anthracene
79. Benzo(g,h,i)perylene (1,12-Benzoperylene)
80. Fluorene
81. Phenanthrene
82. Dibenzo(a,h)anthracene (1,2,5,6-Dibenzanthracene)
83. Indeno(1,2,3-c,d)pyrene (2,3-o-phenylpyrene)
84. Pyrene
85. *Tetrachloroethylene (1,1,2,2-Tetrachloroethene)
86. *Toluene
87. *Trichloroethylene
88. *Vinyl chloride (Chloroethylene)

Pesticides and Metabolites

89. *Aldrin [3]
90. *Dieldrin [3]
91. *Chlordane (technical mixture and metabolites)

*DDT and Metabolites

92. 4,4'-DDT [3]
93. 4,4'-DDE (p,p'DDX) [3]
94. 4,4'-DDD (p,p'TDE) [3]

*Endosulfan and Metabolites

95. α-Endosulfan-Alpha [3]
96. β-Endosulfan-Beta [3]
97. Endosulfan sulfate [3]

*Endrin and Metabolites

98. Endrin [3]
99. Endrin aldehyde [3]

*Heptachlor and Metabolites

100. Heptachlor [3]
101. Heptachlor epoxide [3]

*Hexachlorocyclohexane (all isomers)

102. α-BHC-Alpha [3]
103. β-BHC-Beta [3]
104. γ-BHC (Lindane)-Gamma [3]
105. Δ-BHC-Delta [3]

*Polychlorinated biphenyls (PCB's)

106. PCB-1242 (Arochlor 1242) [1,3]
107. PCB-1254 (Arochlor 1254) [1,3]
108. PCB-1221 (Arochlor 1221) [1,3]
109. PCB-1232 (Arochlor 1232) [1,3]
110. PCB-1248 (Arochlor 1248) [1,3]
111. PCB-1260 (Arochlor 1260) [1,3]
112. PCB-1016 (Arochlor 1016) [1,3]

Table 1-1 continued

113.	*Toxaphene
114.	*Antimony (Total)
115.	*Arsenic (Total)
116.	*Asbestos (Fibrous)[2]
117.	*Beryllium (Total)
118.	*Cadmium (Total)
119.	*Chromium (Total)
120.	*Copper (Total)
121.	*Cyanide (Total)[2]
122.	*Lead (Total)
123.	*Mercury (Total)
124.	*Nickel (Total)
125.	*Selenium (Total)
126.	*Silver (Total)
127.	*Thallium (Total)
128.	*Zinc (Total)
129.	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

*Specific compounds and chemical classes as listed in the Consent Decree (8ERC 2120).
[1]Not included in the list at the start of the refining screening study.
[2]Not included in this report. Cyanide data will be included in a future report. Asbestos analyses were not conducted due to limitations in the available analytical procedures.
[3]API analyses conducted by GC/MS the base/neutral organic extractable fraction.

RADIAN CORPORATION

2.0 WASTEWATER SAMPLING

The initial EPA refinery sampling effort was directed toward a screening survey of 12 refineries during March-July, 1977. An additional five refineries were sampled during April-June, 1977. At certain sites, Exxon R & E and individual company personnel obtained duplicate samples in parallel with EPA sampling teams for subsequent analysis by API contractors. The EPA provided duplicate samples to refineries where requested. Some selected EPA duplicate samples, were subsequently analyzed by some refinery personnel and/or API contractors. The various groups involved in the sampling are identified in Table 2-1. Both API and Burns and Roe (EPA contractor) site designations are included in this table.

Sample collection points at the 17 refineries included intake water, wastewater feed to biotreatment, and final effluent. For the first 12 refineries, EPA obtained composite samples for trace elements and liquid/liquid extractable organics by taking approximately 450-ml aliquots every three hours over a 24-hour period. EPA sampling at the last five refineries employed automatic sampling device that delivered 3.6 liters of sample over a 24-hour period. Grab samples for volatile organics were obtained during the last compositing period of each 24-hour sampling period. Sample sets were obtained for volatile organics, non-volatile organics, and trace elements over three consecutive 24-hour periods. In selected cases 72-hour composites were prepared from the individual 24-hour samples. Grab samples for asbestos analysis were also taken by EPA.

The EPA sampling effort, conducted by RSKERL and Burns and Roe personnel, used the EPA sampling and preservation procedure as outlined in the March, 1977, protocol. However, several notable exceptions occurred. These included: the addition of

TABLE 2-1. SAMPLING PARTICIPANTS IN THE PETROLEUM REFINING SCREENING SURVEY

API Site Designation	Burns & Roe Site Designation	API Sampling	EPA Sampling
1	L	--	RSKERL[1]/Burns & Roe
2	N	Exxon R & E	RSKERL/Burns & Roe
3	A	--	RSKERL/Burns & Roe
4	D	--	RSKERL/Burns & Roe
5	E	--	RSKERL/Burns & Roe
6	F	--	RSKERL/Burns & Roe
7	P	Exxon R & E	RSKERL/Burns & Roe
8	O	--	RSKERL/Burns & Roe
9	B	Exxon R & E	RSKERL/Burns & Roe
10	H	--	RSKERL/Burns & Roe
11	K	--	RSKERL/Burns & Roe
12	M	--	RSKERL/Burns & Roe
13	C	--	RETA[2]/Burns & Roe
14	G	--	RETA/Burns & Roe
15	I	--	RETA/Burns & Roe
16	J	--	RETA/Burns & Roe
17	Q	--	RETA/Burns & Roe

[1]R.S. Kerr Environmental Research Laboratory.[11]

[2]Ryckman, Edgerly, Tomlinson and Associates.[11]

trace element samples to bottles previously charged with nitric acid preservative; the collection of volatile organic samples and blanks with head space volumes; the collection of trace element samples in containers that were not previously acid-washed; and the collection of samples by manual grab and composite techniques rather than with an automatic sampler. Sampling at the last five refineries followed the revised April, 1977, protocol utilizing automatic sampling techniques.

3.0 SAMPLE ANALYSES

Samples obtained by Exxon R & E, other companies and EPA were analyzed during the API study for the inorganic and organic Priority Pollutants. A summary of the API and EPA participants who conducted analyses is presented in Table 3-1.

In general all participants employed the EPA analytical protocol dated March, 1977, for the analyses. Analytical deviations from the EPA protocol are listed in the following table.

Participant	Parameter	Method
Radian Corp.	Trace Elements	AA, Digestion for Total Elements
Radian Corp.	PCBs & Pesticides	GC/MS
Exxon R & E	Volatile Organohalides	Bellar-GC/microcoulometric (1)
Exxon R & E	Volatile Aromatic Hydrocarbons	Grob - GC/FID (4, 5, and 6)
Exxon R & E	PNAs	GC/UV (2, 3, 7, and 9)
Exxon R & E	Selected Organics	Column Chromatography followed by GC, MS, or IR (10)

Specificity and/or lower limits of detection for each of the deviating methods are equivalent to or better than those for the methods outlined in the EPA protocol. A detailed description of all analytical techniques employed is provided in Appendix A.

In addition to the analyses of collected wastewater samples, the API study included special analyses to define the reliability of the EPA protocol. These included duplicate and spiked samples. A description of this work is included in Appendix A.

TABLE 3-1. ANALYTICAL PARTICIPANTS IN THE PETROLEUM REFINING SCREENING SURVEY

Laboratory	Refineries	Volatile Organics	Liquid/Liquid Extractable Organics	Trace Elements
EPA FUNDED				
RSKERL	1-12			X
RETA	13-17	X	X	X
MRI	1-6	X	X	
NUS	7-12	X	X	
API OR COMPANY FUNDED				
Exxon R & E	2,7,9	X	X	X
Radian	2,7,9,11	X	X	X
Environmental Analysis, Inc.	4			X
Company	5	X	X	X
Spectrix	5	X	X	
Company	6	X	X	X
Company	7	X	X	X
Edna Wood Laboratories	8			X
Company	11			X
Company	16			X

4.0 ANALYTICAL RESULTS

The reliability and ultimate usefulness of analytical data depend on several field and laboratory factors. They include: the measures taken to avoid field and laboratory sample contamination, the methods utilized for the preservation and transportation of samples, the adequacy of the methods applied for the isolation and concentration of the species and the accuracy of the techniques applied for the final analytical measurements. Therefore, unless these factors are fully defined for a given sampling and analytical protocol all analytical results must be viewed with discretion.

The adequacy of the EPA sampling and analytical protocol, which was employed, with the exception of the deviations outlined in Section 3.0, in the API study has not been fully defined. Therefore, all numerical analytical data presented must be viewed as being approximate rather than absolute values.

The analytical results obtained from the API analyses of refinery wastewater samples and the data gathered from the special analytical studies are summarized in the following subsections. EPA data are provided as a comparison.

The elemental Priority Pollutants were also determined by API participants and the EPA in the intake waters, wastewater feeds to biotreatment and final effluents. Nine petroleum refining facilities were included in the API study, while EPA data are available from 17 facilities[11]. The API and EPA data are summarized in Tables 4-7 through 4-12.

A detailed listing of all organic and elemental Priority Pollutant data generated is given in Appendix A. The volatile

organic pollutant data found in Appendix A represent sample concentrations that are uncorrected with respect to the field sample blanks. The certain instances it was judged highly probable that the field blanks had been contaminated; therefore, correction of the sample concentration was not possible. For example, blank water from Refinery 9 was found to contain methylene chloride at 63 ppb, a value five times greater than that found at any sampling point. Methylene chloride contamination of field blanks was also suspected for samples obtained from Refineries 2, 7, and 11. Examination of the analytical data for the liquid/liquid extractables from the 17 refineries also indicates that contamination with bis(2-ethylhexyl)phthalate was experienced at refineries 13-17.

4.1 Refinery Wastewater

Analyses of wastewater samples for the inorganic and organic priority pollutants were conducted by the API contractors and individual company personnel. Priority Pollutants were determined by API participants in the intake waters, wastewater feeds to biotreatment, and final effluents.

A total of 36 organics and 13 elemental Priority Pollutants were identified by the API study of six refinery effluent streams. Concentrations ranged from <1 to 60 ppb for organics and <1 to 1100 ppb for trace elements. In no case were all identified pollutants found at each refinery.

In the wastewater feed streams to the biological treatment facilities, 45 organics ranging from <1 to 44,000 ppb and 13 trace elements ranging from <1 to 9,600 ppb were found.

Corresponding refinery intake water samples were found to contain 40 organics ranging from <1 to 150 ppb and 13 trace

TABLE 4-1. FREQUENCY AND CONCENTRATION RANGE OF ORGANIC PRIORITY POLLUTANTS IN REFINERY INTAKE WATERS[1] API DATA

Compound	Frequency of Detection[2]	Concentration Range, ppb Minimum Value	Concentration Range, ppb Maximum Value	Number of Reported Values[3]
Chloromethane[4]	1	D(<.5)	D(<.5)	1
Methylene chloride[4]	6	0.4	80	18
1,1-Dichloroethane[4]	1	4	7.6	3
Trans-1,2,-dichloroethylene	1	1	4	3
Chloroform[4]	4	D(<.5)	37	8
1,2-Dichloroethane[4]	2	D(<.5)	3.5	4
1,1,1-Trichloroethane[4]	5	1	58	10
Carbon Tetrachloride[4]	1	0.5	2	3
Bromodichloromethane[4]	1	3	15	3
1,2-Dichloropropane[4]	1	D(<1)	1	2
Trichloroethylene	3	D(<1)	1	5
Benzene[4]	6	D(<1)	40	13
1,1,2,2-Tetrachloroethene	1	1	1	1
Toluene[4]	6	D(<1)	15	13
Ethylbenzene[4]	6	D(<.5)	D(<20)	14
Naphthalene[4]	3	D(<2)	D(<5)	3
Acenaphthylene[4]	2	D(<2)	D(<40)	2
Acenaphthene[4]	3	D(<2)	D(<40)	3
Phenanthrene/Anthracene[5]	2	3	146	2
Diethyl phthalate	4	2.9	20	4
Fluoranthene	1	3.4	3.4	1
Pyrene	3	0.2	65	3
Di-n-butyl phthalate	4	1	20	4
Butyl benzyl phthalate	1	2	2	1
Chrysene/Benz(a)anthracene[5]	1	76	76	1
Chrysene	1	0.3	0.3	1
Bis(2-ethylhexyl)phthalate	5	D(<1)	16	5
Benz(a)Anthracene	1	0.1	0.1	1
1-Benzo(b)/(k)fluoranthene[5]	1	3.2	3.2	1
Benzo(a)pyrene[4]	4	0.03	8	4
Indeno(1,2,3-c,d)pyrene	1	0.4	0.4	1
Benzo(g,h,i)perylene	1	2.5	2.5	1
Phenol	2	D(<1)	4	2
2,4-Dimethylphenol	1	5	5	1
2-Nitrophenol	2	D(<1)	D(<1)	2
2,4-Dichlorophenol	1	D(<1)	D(<1)	1
4-Nitrophenol	1	4	4	1
4,6-Dinitro-o-cresol	2	D(<1)	D(<1)	2
Pentachlorophenol	1	D(<1)	D(<1)	1

NOTES:

D(X) - Compound was detected at some concentration less than X, but the concentration could not be quantified.

[1]Organic Priority Pollutant data from six refineries only as summarized below:

Company	5, 6, 7
Radian	2, 7, 9, .11
Exxon R&E	2, 7, 9
Other	5

[2]Number of refineries where the compound was detected by one or more of the reporting laboratories.

[3]Does not include duplicate determinations.

[4]Some values for this compound were obtained by a method other than the EPA Protocol.

[5]Combined value for these unresolved isomers.

TABLE 4-2. FREQUENCY AND CONCENTRATION RANGE OF ORGANIC PRIORITY POLLUTANTS IN REFINERY WASTEWATER FEEDS TO BIOTREATMENT[1] API DATA

Compound	Frequency of Detection[2]	Concentration Range, ppb Minimum Value	Concentration Range, ppb Maximum Value	Number of Reported Values[3]
Chloromethane[4]	1	17000	17000	1
Methylene chloride[4]	5	D(<.5)	300	23
1,1-Dichloroethane[4]	1	D(<1)	D(<1)	3
1,1-Dichloroethylene	1	10	10	1
trans-1,2-Dichloroethylene	1	1	1	1
Chloroform[4]	4	0.9	30	18
1,2-Dichloroethane[4]	3	D(<.5)	51	9
1,1,1-Trichloroethane[4]	3	D(<1)	15	8
Carbon tetrachloride[4]	1	D(<1)	2	4
Bromodichloromethane	1	D(<1)	D(<1)	3
1,2-Dichloropropane	1	D(<1)	40	2
trans-1,3-Dichloropropene	2	2	3	2
Trichloroethylene	4	D(<1)	5	8
cis-1,3-Dichloropropene	1	20	20	1
Benzene[4]	5	D(<10)	31000	19
Bromoform	1	D(<1)	D(<1)	2
1,1,2,2-Tetrachloroethene[4]	2	D(<.5)	6	7
1,1,2,2-Tetrachloroethane	1	2	2	2
Toluene[4]	5	40	44000	19
Ethylbenzene[4]	4	1	460	17
Naphthalene[4]	4	22	5200	9
Acenaphthylene[4]	2	D(<40)	200	3
Acenaphthene[4]	2	9	200	4
Fluorene[4]	4	2.9	62	6
Phenanthrene/Anthracene[5]	5	2	110	6
Phenanthrene[4]	3	2.7	32	3
Anthracene[4]	1	0.1	0.1	1
Diethyl phthalate	4	2	60	4
Fluoranthene[4]	5	0.04	23	10
Pyrene[4]	6	0.06	6.9	12
Di-n-butyl phthalate	3	D(<1)	45	4
Chrysene/Benz(a)anthracene[5]	4	0.3	16	4
Chrysene[4]	3	0.3	9	4
Benz(a)anthracene[4]	3	0.1	1.4	3
Butyl benzyl phthalate	1	6	6	1
bis(2-Ethylhexyl) phthalate	4	1.8	6	4
Benzo(b)/(k)fluoranthene[5]	1	0.9	0.9	1
Benzo(b)fluoranthene[4]	1	0.3	0.3	1
Benzo(k)fluoranthene[4]	1	0.3	0.3	1
Benzo(a)pyrene[4]	4	0.02	7.8	6
Indeno(1,2,3-c,d)pyrene[4]	2	0.02	0.5	2
Dibenzo(a,h)anthracene[4]	2	0.07	0.4	2
Benzo(g,h,i)perylene[4]	4	0.2	1.2	4
Phenol[4]	6	6	26000	10
2,4-Dimethylphenol	5	8	3000	7
2-Chlorophenol	1	1	1	1
2,4-Dichlorophenol	1	D(<1)	D(<1)	1
p-Chloro-m-cresol	1	D(<1)	D(<1)	1
Pentachlorophenol	1	D(<1)	D(<1)	1

NOTES:

D(X) - Compound was detected as some concentration less than X, but the concentration could not be quantified.

[1]Organic Priority Pollutant data from six refineries only as summarized below:

Company	5, 6, 7
Radian	2, 7, 9, 11
Exxon R&E	2, 7, 9
Other	5

[2]Number of refineries where the compound was detected by one or more of the reporting laboratories.

[3]Does not include duplicate determinations.

[4]Some values for this compound were obtained by a method other than the EPA Protocol.

[5]Combined value for these unresolved isomers.

TABLE 4-3. FREQUENCY AND CONCENTRATION RANGE OF ORGANIC PRIORITY POLLUTANTS IN REFINERY FINAL EFFLUENTS[1] API DATA

Compound	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values[3]
		Minimum Value	Maximum Value	
Chloromethane[4]	1	D(<.5)	D(<.5)	1
Methylene chloride[4]	5	D(<.5)	55	16
1,1-Dichloroethylene[4]	1	D(<1)	10	3
1,1-Dichloroethane	1	D(<1)	D(<1)	3
Chloroform[4]	4	D(<.5)	16	12
1,2-Dichloroethane[4]	3	D(<.5)	D(<1)	7
1,1,1-Trichloroethane[4]	2	D(<1)	3	6
Carbon tetrachloride[4]	1	D(<1)	D(<1)	3
Bromodichloromethane	1	D(<1)	D(<1)	3
1,2-Dichloropropane[4]	1	D(<1)	5	2
trans-1,3-Dichloropropene[4]	1	1	1	1
Trichloroethylene	4	D(<1)	3	7
Benzene[4]	5	D(<1)	30	12
Toluene[4]	5	D(<1)	60	13
Ethylbenzene[4]	4	D(<1)	D(<40)	12
Naphthalene[4]	3	0.1	50	3
Acenaphthylene[4]	2	D(<10)	D(<10)	2
Acenaphthene[4]	2	D(<10)	40	2
Fluorene	1	0.6	0.6	1
Phenanthrene/Anthracene[5]	1	0.4	0.4	1
Diethyl phthalate	3	4.3	7	3
Fluoranthene[4]	3	0.1	0.3	3
Pyrene[4]	4	D(<.1)	1.9	7
Di-n-butyl phthalate	4	D(<1)	32	4
Chrysene/Benz(a)anthracene[5]	3	0.1	1.4	3
Chrysene[4]	1	0.2	0.2	1
Benz(a)anthracene[4]	2	0.01	0.08	2
bis(2-Ethylhexyl) phthalate	4	2	15	4
Benzo(b)/(k)fluoranthene[5]	1	0.2	0.2	1
Benzo(a)pyrene[4]	3	0.08	0.9	5
Benzo(g,h,i)perylene	1	0.2	0.2	1
Phenol	2	1.9	59	2
2,4-Dimethylphenol	3	2.2	8	3
p-Chloro-m-cresol	1	0.2	0.2	1
4,6-Dinitro-o-cresol	1	D(<1)	D(<1)	1

NOTES:

D(X) - Compound was detected at some concentration less than X, but the concentration could not be quantified.

[1]Organic Priority Pollutant data from six refineries only as summarized below:

Company	5, 6, 7
Radian	2, 7, 9, 11
Exxon R&E	2, 7, 9
Other	5

[2]Number of refineries where the compound was detected by one or more of the reporting laboratories.

[3]Does not include duplicate determinations.

[4]Some values for this compound were obtained by a method other than the EPA Protocol.

[5]Combined value for these unresolved isomers.

TABLE 4-4. FREQUENCY AND CONCENTRATION RANGE OF ORGANIC PRIORITY POLLUTANTS IN REFINERY INTAKE WATERS[1] EPA DATA

Compound	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values
		Minimum Value	Maximum Value	
Methylene chloride	5	D(<10)	G(100)	5
Chloroform	1	70	70	1
1,1,1-Trichloroethane	2	D(<10)	G(50)	2
Carbon tetrachloride	1	G(50)	G(50)	1
Trichloroethylene	1	20	20	1
1,1,2,2-Tetrachloroethene	1	50	50	1
1,4-Dichlorobenzene	1	D(<.5)	D(<.5)	1
1,2-Dichlorobenzene	1	D(<.5)	D(<.5)	1
Naphthalene	2	1	1.8	2
Acenaphthylene	1	0.2	0.2	1
Acenaphthene	2	1.8	29	2
Fluorene	1	1	1	1
Phenanthrene/Anthracene[3]	5	D(<.1)	160	5
Dimethylphthalate	1	20	20	1
Diethylphthalate	1	D(<10)	D(<10)	1
Fluoranthene	3	D(<.2)	29	3
Pyrene	3	D(<.1)	143	3
Di-n-butyl phthalate	4	0.2	30	4
Chrysene/Benz(a)anthracene[3]	1	49	49	1
bis(2-Ethylhexyl)phthalate	5	110	1100	5
Benzo(a)pyrene	1	33	33	1
Phenol	2	10	10	2

NOTES:

D(X) - Compound was detected at some concentration less than X, but the concentration could not be quantified.
G(X) - Greater than the value X.
[1]Results from Refineries 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, and 17, except volatile organics from Refineries 1, 2, 3, 4, 5, and 6 only.
[2]Number of refineries where the compound was detected by one or more of the reporting laboratories.
[3]Combined value for these unresolved isomers.

TABLE 4-5. FREQUENCY AND CONCENTRATION RANGE OF ORGANIC PRIORITY POLLUTANTS IN REFINERY WASTEWATER FEEDS TO BIOTREATMENT[1] EPA DATA

Compound	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values
		Minimum Value	Maximum Value	
Chloromethane	1	G(100)	G(100)	1
Bromomethane	1	D(<10)	D(<10)	1
Methylene chloride	5	10	G(100)	7
trans-1,2-Dichloroethylene	1	20	20	1
Chloroform	3	D(<5)	15	6
1,2-Dichloroethane	1	D(<10)	D(<10)	1
Bromodichloromethane	3	D(<10)	D(<10)	3
1,2-Dichloropropane	2	D(<10)	D(<10)	2
Chlorodibromomethane	1	107	107	1
Benzene	5	90	G(100)	7
1,1,2,2-Tetrachloroethene	1	G(50)	G(50)	1
Toluene	5	G(100)	G(100)	7
Ethylbenzene	5	20	G(100)	7
Acrolein	1	D(<10)	D(<10)	1
Naphthalene	8	27	1100	11
Acenaphthylene	2	4	87	2
Acenaphthene	5	37	3000	5
Fluorene	3	80	304	4
N-Nitroso diphenylamine	1	D(<10)	D(<10)	1
Phenanthrene/Anthracene[3]	9	0.6	1100	13
Diethyl phthalate	1	12	12	1
Fluoranthene/Pyrene	2	20	40	3
Fluoranthene	3	2.5	8.5	3
Pyrene	6	0.7	20	7
Di-n-butyl phthalate	1	1.3	1.3	1
Chrysene/Benz(a)anthracene[3]	3	6.5	50	6
Chrysene	4	0.1	20	6
bis(2-Ethylhexyl)phthalate	5	50	1100	11
Benzo(a)pyrene	1	9.5	9.5	1
Phenol	9	13	16000	15
2,4-Dimethylphenol	4	71	750	7
p-Chloro-m-cresol	1	10	10	1
Pentachlorophenol	1	850	850	1

NOTES:

D(X) - Compound was detected at some concentration less than X, but the concentration could not be quantified.

G(X) - Greater than the value X.

[1]Results from Refineries 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, and 17, except volatile organics from Refineries 1, 2, 3, 4, 5, and 6 only.

[2]Number of refineries where the compound was detected by one or more of the reporting laboratories.

[3]Combined value for these unresolved isomers.

TABLE 4-6. FREQUENCY AND CONCENTRATION RANGE OF ORGANIC PRIORITY POLLUTANTS IN REFINERY FINAL EFFLUENTS[1] EPA DATA

Compound	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values
		Minimum Value	Maximum Value	
Methylene chloride	4	D(<10)	60	4
Chloroform	1	D(<5)	D(<5)	1
Benzene	1	6	6	1
1,1,2,2-Tetrachloroethene	1	D(<10)	D(<10)	1
Toluene	1	35	35	1
Naphthalene	1	0.1	0.1	1
Acenaphthene	1	6	6	1
Phenanthrene/Anthracene[3]	2	0.8	D(<10)	2
Dimethylphthalate	1	3	3	1
Diethylphthalate	2	D(<10)	30	2
Fluoranthene	1	D(<.1)	D(<.1)	1
Pyrene	3	D(<.1)	7	3
Chrysene/Benz(a)anthracene[3]	1	0.8	0.8	1
Chrysene	3	D(<.1)	1.4	3
bis(2-Ethylhexyl) phthalate	5	190	2000	5
Benzo(a)pyrene	2	1.3	2.9	2

NOTES:

D(X) - Compound was detected at some concentration less than X, but the concentration could not be quantified.
G(X) - Greater than the value X.
[1]Results from Refineries 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, and 17, except volatile organics from Refineries 1, 2, 3, 4, 5, and 6 only.
[2]Number of refineries where the compound was detected by one or more of the reporting laboratories.
[3]Combined value for these unresolved isomers.

TABLE 4-7. FREQUENCY AND CONCENTRATION RANGE OF TRACE ELEMENTS IN REFINERY INTAKE WATERS[1]
API DATA

Element	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values[3]
		Minimum Value	Maximum Value	
Zinc	7	10	230	14
Chromium	6	2	1,300	14
Copper	6	20	290	11
Lead	7	1.2	30	12
Beryllium	2	.4	1.1	4
Antimony	5	.3	30	9
Thallium	1	15	15	1
Nickel	6	1	70	10
Arsenic	4	10	22	6
Selenium	5	3	19	9
Silver	4	0.1	9	5
Cadmium	4	.2	4	6
Mercury	5	.13	.4	5

[1]Data from nine refineries only; reporting laboratories summarized below:

Company: 2*, 4*, 5, 6, 7, 8, 9, 11, 16* (*Chromium only)
Radian : 2, 7, 9

[2]Number of refineries where the element was detected by one or more of the laboratories.

[3]Does not include duplicate determinations.

TABLE 4-8. FREQUENCY AND CONCENTRATION RANGE OF TRACE ELEMENTS IN REFINERY WASTEWATER FEEDS TO BIOTREATMENT[1] API DATA

Element	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values[3]
		Minimum Value	Maximum Value	
Zinc	7	12	9,600	15
Chromium	9	23	1,300	28
Copper	6	5	460	13
Lead	7	4	75	15
Beryllium	3	.3	2.2	7
Antimony	5	.4	240	11
Thallium	4	1	190	9
Nickel	6	1.5	120	12
Arsenic	6	6	50	10
Selenium	5	8	35	11
Silver	4	0.2	160	6
Cadmium	4	0.6	13	7
Mercury	5	0.9	0.8	6

[1]Data from nine refineries only; reporting laboratories summarized below:

Company: 2*, 4*, 5, 6, 7, 8, 9, 11, 16* (*Chromium only)
Radian: 2, 7, 9

[2]Number of refineries where the element was detected by one or more of the reporting laboratories.

[3]Does not include duplicate determinations.

TABLE 4-9. FREQUENCY AND CONCENTRATION RANGE OF TRACE ELEMENTS IN REFINERY FINAL EFFLUENTS[1] API DATA

Element	Frequency of Detection[2]	Concentration Range, ppb		Number of Reported Values[3]
		Minimum Value	Maximum Value	
Zinc	7	10	190	14
Chromium	9	11	1,100	21
Copper	6	3	130	12
Lead	7	2	46	11
Beryllium	3	0.2	2.1	6
Antimony	5	5.3	190	10
Thallium	3	4.8	9.5	4
Nickel	6	0.9	82	12
Arsenic	5	2	70	8
Selenium	5	9	74	9
Silver	4	0.8	170	5
Cadmium	4	0.8	16	6
Mercury	5	0.7	0.8	5

[1]Data from nine refineries only; reporting laboratories summarized below:

Company: 2*, 4*, 5, 6, 7, 8, 9, 11, 16* (*Chromium only)
Radian: 2, 7, 9

[2]Number of refineries where the element was detected by one or more of the reporting laboratories.

[3]Does not include duplicate determinations.

TABLE 4-10. FREQUENCY AND CONCENTRATION RANGE OF TRACE ELEMENTS IN REFINERY INTAKE WATERS[1] EPA DATA

Element	Frequency of Detection[2]	Concentration Range, ppb Minimum Value	Maximum Value	Number of Reported Values
Zinc	15	15	120	15
Chromium	13	1	60	13
Copper	10	1	210	10
Lead	8	1	40	8
Antimony	1	1	1	1
Thallium	1	3	3	1
Nickel	5	1	58	5
Arsenic	5	3	27	5
Selenium	6	2	13	11
Cadmium	1	2	2	1
Mercury	5	0.1	6	13

[1]RSKERL and RETA data from all seventeen refineries.

[2]Number of refineries where the element was detected by one or more of the reporting laboratories.

TABLE 4-11. FREQUENCY AND CONCENTRATION RANGE OF TRACE ELEMENTS IN REFINERY WASTEWATER FEEDS TO BIOTREATMENT[1] EPA DATA

Element	Frequency of Detection[2]	Concentration, ppb		Number of Reported Values
		Minimum Value	Maximum Value	
Zinc	17	24	4,800	58
Chromium	15	1	4,900	53
Copper	14	2	500	30
Lead	10	2	2,000	27
Antimony	4	1	360	4
Thallium	1	3	6	4
Nickel	10	1	77	15
Arsenic	7	3	480	16
Selenium	5	4	31	44
Silver	1	1	2	2
Cadmium	3	3	16	6
Mercury	5	0.1	9	25

[1]RSKERL and RETA data from all seventeen refineries.

[2]Number of refineries where the element was detected by one or more of the reporting laboratories.

TABLE 4-12. FREQUENCY AND CONCENTRATION RANGE OF TRACE ELEMENTS IN REFINERY FINAL EFFLUENTS[1] EPA DATA

Element	Frequency of Detection[2]	Concentration, ppb		Number Reported Results
		Minimum Value	Maximum Value	
Zinc	16	25	700	22
Chromium	15	1	1,000	18
Copper	10	3	180	10
Lead	5	2	58	8
Antimony	3	1	370	3
Thallium	2	3	12	5
Nickel	5	3	58	8
Arsenic	4	5	900	7
Selenium	7	3	32	21
Silver	1	15	15	1
Cadmium	2	1	5	2
Mercury	5	0.5	6	10

[1]RSKERL and RETA data from all seventeen refineries.

[2]Number of refineries where the element was detected by one or more of the reporting laboratories.

metals ranging from <1 to 1300 ppb. The organics in the intake waters occurred infrequently among the refineries and may not be representative of waters in all geographic areas where refineries are located.

Eighteen organics and 12 elemental Prirority Pollutants were identified in 17 refinery effluents by EPA. Concentrations ranged from <1 to 2000 ppb for organics and from <1 to 1000 ppb for trace elements. EPA found 33 organics and 12 trace elements in the wastewater feeds to biotreatment. In these streams, organics ranged from <1 to 16,000 ppb, while trace elements ranged from <1 to 4900 ppb. Intake water analyses by EPA gave concentrations of 24 organics ranging from <1 to 1100 ppb and 10 trace elements ranging from <1 to 210 ppb.

4.2 Special Analytical Studies

Previously analyzed final effluent samples from Refineries 7 and 9 were spiked with PNAs, phthalate esters, and phenols to determine the recoveries of these classes of materials. The spiked samples were solvent extracted and analyzed according to the EPA Protocol by Radian and data from these studies are summarized below.

Species	Concentration Range	Range of Recovery
PNAs	5 - 7 ppb	46 - 70%
PNAs	18 - 33 ppb	67 - 84%
PNAs	54 - 220 ppb	19 - 112%
Phthalate Esters	6 - 25 ppb	4 - 7%
Phthalate Esters	140 - 610 ppb	41 - 420%
Phenols	4 - 9 ppb	68 - 92%
Phenols	14 - 29 ppb	55 - 93%
Phenols	84 - 330 ppb	25 - 89%

In addition, previously analyzed final effluent samples from Refineries 2, 7, and 9 were spiked with the elemental Priority Pollutants at levels from approximately 0.05 ppb to 500 ppb and reanalyzed. Average recovery ranged from 72% to 139%.

A single interlaboratory study was conducted on a spiked final effluent from Refinery 7. Midwest Research Institute (MRI) analyzed the same spiked effluent extract according to the EPA Protocol after an elasped time of approximately three months. Analytical data from this study are summarized below.

Compound	Calculated* Concentration (ppb)	Radian (ppb)	MRI (ppb)
Naphthalene	74	19	N.D.
Fluorene	54	51	66
Phenanthrene/Anthracene**	78	88	40
Pyrene	33	24	4
Di-n-butyl phthalate	140	420	194
bis(2-ethylhexyl) phthalate	220	190	69

(N.D. = Not detected.)

*Concentration in sample based on the first analysis by Radian plus the concentration of the spike

**Sample spiked with phenanthrene.

Complete analytical data obtained from the studies are presented in Appendix A.

5.0 DISCUSSION OF ANALYTICAL DATA

In a data base of this type and importance, it is essential to evaluate the quality of the data developed. Analyses of parallel samples at several refineries make it possible to compare the data from different laboratories to obtain an indication of the reproducibility of the sampling and analytical methods employed. The special studies discussed in Section 4.2 can also be used to evaluate the quality of the data base.

However, these limited studies do not fully define the adequacy of the sampling and analytical protocol. Therefore, the analytical data must be viewed as approximate instead of exact and interpretations must be made with discretion. Factors that were used to judge the reliability of the data are discussed in detail in the Subsections below.

5.1 Interference and Contamination of the Samples

Field blanks were analyzed by the various laboratories as a check on potential contamination. A summary of the blank sample data is included in Appendix B. The analytical data indicate that many of the blanks were contaminated. Often there was a greater concentration of a component in the blank than in the samples associated with that blank. For example, blank water from Refinery 9 was found to contain methylene chloride at 63 ppb, a value five times greater than that found at any sampling point. This makes blank correction of sample concentrations impossible. The apparent case of contamination by the volatile compounds listed in Table B-2 forces one to question the concentrations of these compounds found in other samples at other sites.

5.2 Recoveries - Spiked Samples

The determination of recoveries from spiked samples provides an indication of the accuracy to be expected from the application of an analytical technique. As discussed in Section 4.2, five samples previously analyzed were spiked with various compounds in an attempt to determine the recoveries for samples analyzed. Data from Radian are reported in Section 4.2 and Appendix A. A statistical analysis of the trace element data is included in Appendix B, Table B-6.

The recoveries for PNAs are similar for all the compounds, ranging from 26% to 116% for spikes from 54 to 220 ppb, but declining significantly at concentrations below 30 ppb. For phenols the recoveries ranged from 41% to 90% for concentrations greater than 80 ppb. For the trace elements the recoveries ranged from 34% to 193% for the different species and were quite variable between samples. The EPA reported recovery studies for mercury show a range of 68% to 97% for samples spiked at 0.3 to 0.5 ppb. For phthalates, recoveries ranged from 4% to 300%.

A wide range of spiked sample recoveries indicates the possible inaccuracy of a given analytical protocol.

5.3 Repeatability of Analytical Methods - Duplicate Analyses

It is important to document the repeatability of the various test methods used to analyze the samples. The repeatability is a measure of the difference one might expect on a repeat analysis of the same sample by the same laboratory.

Appendix B, Table B-3, describes the results for duplicate analyses performed during this study for which some

quantitative data were reported. The percent difference between duplicates was quite variable, ranging from 0 to 105%. The median percent difference for the company data was 0% for the volatile organics and 14% for liquid/liquid extractable organics. The median percent difference for the volatile organics reported by Spectrix (Refinery 5) was 67%. The standard deviation of all API and company data averages about 30% for both the volatile organics and the liquid/liquid extractable organics.

Estimates of the analytical repeatability can also be derived from the spiked sample studies (Table A-4). An analysis of these data indicates that for the PNAs, the intralaboratory standard deviation is about 16% for concentrations greater than 40 ppb, while the standard deviation increases to 45% for samples at the one ppb level. For the phenols, the standard deviation is about 35% for samples greater than 20 ppb and increases to about 70% for samples at one ppb.

Estimates from the EPA reported quality control study of mercury show that the standard deviation is about 0.04 ppb (about 10%) for samples in the 0.3 to 0.5 ppb range.

5.4 Reproducibility of Sampling and Analytical Methods

Since analyses were conducted by different laboratories in some of the refineries studied, comparisions of the data from the laboratories gives an indication of the reproducibility of the analytical methods. The following laboratory comparisions are discussed and analyzed in Appendix B:

Comparisions Made	Refineries From Which Data Was Analyzed: Volatile Organics	Liquid/Liquid Extractable Organics	Trace Elements
EPA Labs vs. Radian	2	2	2, 7, 9
EPA Labs vs. Company Labs	2	2, 6	2, 7, 9, 11, 16
Radian vs. Company Labs	2, 7, 9	2, 7, 9	2, 7, 9
Radian vs. Other Contract Labs		7	

Since much of the data is reported as "not detected," "detected less than some value," or as "greater than some value," a quantitative comparison of the laboratories is not straight-gorward. In Appendix B, qualitative comparisons are made and a technique is developed to convert the qualitative data to quantitative data which allows comparisons to be made using scatter plots.

The comparisons show that laboratories frequently differ by greater than 75% when quantitative data is reported. There are examples where the differences are an order of magnitude. These extreme differences between laboratories are a composite of a number of effects including repeatability of the test method, interferences from the contamination of samples, and variability of recoveries, as well as the inherent variability between laboratories using the same test method.

5.5 PNA Comparisons

In four refineries, analyses for PNAs were conducted by two independent methods; the EPA GC/MS technique and the highly specific Exxon R & E GC/UV method. Selected comparative data for the two methods are summarized in Table 5-1.

TABLE 5-1. COMPARISON OF POLYNUCLEAR AROMATIC HYDROCARBON DATA FROM REFINERY 7[1]

Compound	Intake Water			Wastewater Feed to Biotreatment			Final Effluent		
	Radian	Company	ER & E[2]	Radian	Company	ER & E[2,3]	Radian	Company	ER & E[2]
Naphthalene	ND (<0.1)	ND (<1.)	---	1100	5200	---	ND (<0.1)	ND (<1)	---
Fluorene	ND (<0.1)	ND (<1)	---	62	ND (<1)	5	ND (<0.1)	ND (<1)	ND (<0.3)
Phenanthrene	ND (<0.1)[4]	ND (<1)[4]	---	99[4]	ND (<1)[4]	32	ND (<0.1)[4]	ND (<1)[4]	ND (<0.2)
Anthracene			---			ND (<0.3)			ND (<0.01)
Fluoranthene	ND (<0.1)	ND (<1)	ND (<0.03)	23.	ND (<1)	2.0	ND (<0.1)	ND (<1)	ND (<0.05)
Pyrene	ND (<0.1)	ND (<1)	ND (<0.02)	6.9	ND (<1)	6.4	0.3	ND (<1)	0.3
Chrysene	ND (<0.1)[4]	ND (<1)[4]	ND (<0.01)	13.[4]	ND (<1)[4]	2.6	0.1[4]	ND (<1)[4]	ND (<0.02)
Benzo(a)anthracene			ND (<0.01)			1.4			0.01
Triphenylene[5]			ND (<0.01)			1.2			0.3
Benzo(a)pyrene	ND (<0.1)[4]	ND (<1)[4]	0.03	4.4[4]	ND (<1)[4]	1.1	0.4[4]	ND (<1)[4]	0.08
Benzo(e)pyrene[5]			ND (<0.05)			1.3			0.2
Perylene[5]			ND (<0.06)			0.3			ND (<0.1)
Dibenzo(a,h)anthracene	ND (<0.3)	ND (<1)	---	ND (<0.3)	ND (<1)	0.4	ND (<0.3)	ND (<1)	ND (<0.03
Benzo(g,h,i)perylene	ND (<0.2)	ND (<1)	ND (<0.1)	ND (<0.2)	ND (<1)	0.6	ND (<0.2)	ND (<1)	ND (<0.2)

[1]All values in µg/ℓ (ppb).

[2]Analysis by GC-UV method.

[3]Duplicate analyses were performed on this sample point; data presented is from analysis #1.

[4]This is a combined value. The protocol procedure cannot distinguish between these structural isomers.

[5]This compound is not on the list of Priority Pollutants.

NOTES: ND (<X): Compound was not detected; X equals the lowest limit of sensitivity of the method for that sample.
D (<X): Compound was detected at some concentration less than X, but the concentration could not be quantified.

The comparisons have shown that the EPA methodology is incapable of detecting and accurately quantifying individual isomeric PNAs. For example, at Refinery 7, analysis of the final effluent by the EPA GC/MS approach yielded concentrations for chrysene and benzo(a)pyrene of 9.1 and 0.4 ppb, while the values, as obtained by GC/UV, are less than 20% of those reported by GC/MS analysis.

Polynuclear aromatic hydrocarbon data obtained from the analysis of effluents conducted according to the EPA Protocol has been shown to be potentially inaccurate. This is due to the gas chromatographic conditions employed in the analytical methodology. Benzo(a)pyrene, benzo(e)pyrene and perylene and other isomeric PNA groups are not resolved under the chromatographic conditions. Therefore, all isomeric PNAs contained in a group are reported as a single compound. This leads to reported concentrations that are erroneously high.

Therefore, all PNA data obtained according to the EPA Protocol must be viewed with skepticism. Accurate PNA data can be only obtained from the utilization of techniques that differentiate between isomeric species.

5.6 Trace Element Data

Selected parallel samples for the element Priority Pollutants were analyzed by the EPA and API analytical participants. Considerable interlaboratory variation in the analytical data has been found. When quantitative comparisons could be made 42% of the interlaboratory differences exceeded 75%.

The variations can be attributed to several potential factors which include:

- Field or laboratory contamination of the samples
- The interlaboratory analyses of parallel rather than true duplicate sample splits.
- The application of different analytical procedures.

Until the discrepancies in the elemental analytical data are resolved, the concentrations determined must be viewed as being only approximations.

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GLOSSARY

AA. Atomic adsorption spectrometry.

API. American Petroleum Institute.

Bellar technique. An analytical technique for volatile organics in water. Organics are purged from the sample by inert gas stripping and the compounds of interest are trapped on a polymeric adsorbent. The organics are then thermally desorbed onto the head of a gas chromatographic column for analytical measurement.

BATEA. Best available technology economically achievable.

BPCT. Best practical control technology.

Column chromatography. Analytical technique for the separation of organic compounds by adsorption chromatography.

EMSL. U.S. EPA Environmental Monitoring and Support Laboratory.

ER&E. Exxon Research and Engineering.

GC. Gas chromatography.

GC/FID. Gas chromatography employing a flame ionization detector.

GC/MS. Gas chromatography/mass spectrometry.

GC/UV. Gas chromatography/ultraviolet spectrometry.

Grob technique. An analytical technique for volatile organics in water. Organics present in the headspace above the samples are trapped on activated carbon. Organics are then desorbed from carbon by extraction with carbon disulfide. The extract is usually analyzed by gas chromatographic techniques.

Hall detector. An electrolytic conductivity detector for gas chromatography, specific for nitrogen and halogen compounds.

HPLC. High pressure liquid chromatography.

LLE. Liquid/liquid extractable.

MRI. Midwest Research Institute.

MS. Mass spectrometry.

NUS. NUS Corporation.

PARL. Port Arthur Research Laboratories (Texaco).

PCB. Polychlorinated biphenyl.

PNA. Polynuclear aromatic hydrocarbon.

ppb. Parts per billion.

RETA. Ryckman, Edgerley, Tomlinson and Associates.

RSKERL. U.S. EPA Robert S. Kerr Environmental Research Laboratories.

APPENDIX A

ANALYTICAL METHODOLOGY AND ANALYTICAL DATA

APPENDIX A
ANALYTICAL METHODOLOGY AND ANALYTICAL DATA

1.0 INTRODUCTION

This appendix presents the methodologies used in the screening survey for the Priority Pollutants in the petroleum refining industry. Also presented are the analytical results obtained during the course of this program.

GC/MS and trace element procedures which were employed in this study are documented in the EPA report, "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants" dated March, 1977. This manual was prepared by the staff of the Environmental Monitoring and Support Laboratory, Cincinnati, to provide guidelines for the analysis of the Priority Pollutants. This manual will be referred to frequently in the following discussions as the EPA Protocol.

Section 2.0 of this appendix describes the methods employed for the analysis of the organic Priority Pollutants while the trace element procedures are described in Section 3.0. The analytical results are presented in Section 4.0.

2.0 ANALYSIS OF ORGANIC PRIORITY POLLUTANTS

This section describes the analytical methods employed for the determination of the organic Priority Pollutants listed in Table A-1. The compounds listed in this table are classified as either volatile or liquid/liquid extractable organics with the liquid/liquid extractable compounds further separated into base/neutral and acid extractables. The EPA Protocol has recommended separate procedures for the analysis of the compounds in each of these three classes. The protocol procedures are all gas chromatographic/mass spectrometric (GC/MS) methods with the exception of the methods detailed for PCB and pesticide analyses. Other procedures have been developed for the analysis of some or all the organic Priority Pollutants. These methods include conventional gas chromatography (GC), ultraviolet adsorption spectrometry (UV), and high pressure liquid chromatography (HPLC).

During the screening phase of this study, eight laboratories reported values for some or all of the organic Priority Pollutants in 14 refineries. The refineries for which no data concerning the organic Priority Pollutants were reported at the time of this report were the refineries designated 8, 10, and 12. The laboratories which have reported data are summarized below:

EPA Subcontractors

- Midwest Research Institute (MRI) - Refineries 1-6
- Ryckman, Edgerley, Tomlinson, & Associates (RETA) - Refineries 13-17

API Contractors

- Radian Corporation - Refineries 2,7, 9, & 11
- Exxon Research & Engineering Company (ER&E) - Refineries 2,7,9

TABLE A-1. ORGANIC PRIORITY POLLUTANTS

VOLATILE

Acrolein	1,2-Dichloropropane
Acrylonitrile	1,3-Dichloropropene
Benzene	Methylene chloride
Carbon tetrachloride	Methyl chloride
Chlorobenzene	Methyl bromide
1,2-Dichloroethane	Bromoform
1,1,1-Trichloroethane	Dichlorobromomethane
1,1-Dichloroethane	Trichlorofluoromethane
1,1,2-Trichloroethane	Dichlorodifluoromethane
1,1,2,2-Tetrachloroethane	Chlorodibromomethane
Chloroethane	Tetrachloroethylene
2-Chloroethyl vinyl ether	Toluene
Chloroform	Trichloroethylene
1,1-Dichloroethylene	Vinyl chloride
1,2-trans-Dichloroethylene	Ethylbenzene

LIQUID/LIQUID EXTRACTABLES

Base/Neutral Extract

1,3-Dichlorobenzene	Dibenzo(a,h)anthracene
1,4-Dichlorobenzene	Benzo(g,h,i)perylene
Hexachloroethane	4-Chlorophenyl phenyl ether
1,2-Dichlorobenzene	Endrin aldehyde
Hexachlorobutadiene	Toxaphene
1,2,4-Trichlorobenzene	Chlordane
Naphthalene	Aldrin
bis(2-Chloroethoxy) methane	Dieldrin
2-Chloronaphthalene	4,4'-DDT
Acenaphthylene	4,4'-DDE
Acenaphthene	4,4'-DDD
Isophorone	α-Endosulfan
Fluorene	β-Endosulfan
2,6-Dinitrotoluene	Endrin
Hexachlorobenzene	Heptachlor
4-Bromophenyl phenyl ether	Heptachlor epoxide
Phenanthrene	α-BHC
Anthracene	β-BHC
Dimethyl phthalate	γ-BHC
Diethyl phthalate	δ-BHC
Fluoranthene	PCB 1242
Pyrene	PCB 1254
Di-n-butyl phthalate	bis(2-Chloroethyl) ether
Butyl benzyl phthalate	N-Nitrosodiphenylamine
Chrysene	3,3'-Dichlorobenzidine
bis(2-Ethylhexyl) phthalate	2,4-Dinitrotoluene
Di-n-octyl phthalate	1,2-Diphenylhydrazine
Benzo(a)anthracene	Nitrobenzene
Benzo(b)fluoranthene	N-Nitrosodimethylamine
Benzo(k)fluoranthene	N-Nitrosodi-n-propylamine
Benzo(a)pyrene	bis(2-Chloroisopropyl) ether
Indeno(1,2;3-c,d)pyrene	Benzidine

Acidic Extract

Phenol	p-Chloro-m-cresol
2-Chlorophenol	2,4,6-Trichlorophenol
2,4-Dimethylphenol	2,4-Dinitrophenol
2-Nitrophenol	4-Nitrophenol
2,4-Dichlorophenol	4,6-Dinitro-o-cresol
	Pentachlorophenol

Company Laboratories

Exxon Research & Engineering Company (ER&E)

Mobil Research & Development Corporation

Shell Development Company

Texaco Port Arthur Research Laboratories (PARL)

Other Laboratories

Spectrix Corporation - Refinery 5

The methods which were utilized by these laboratories are discussed in more detail in the subsequent sections. Table A-2 presents a summary of the methods employed by the various laboratories for each category of the organic Priority Pollutants.

2.1 Analysis of Volatile Organics

Volatile organics are defined in the EPA protocol as "those unambiguous Priority Pollutants associated with the Consent Decree, that are amenable to the purge and trap method." All laboratories which reported results for these compounds utilized a procedure based on removing the volatile compounds by purging with an inert gas and trapping the purged species on a suitable sorbent. The trapped species were then thermally desorbed for analysis. In addition to this procedure, Exxon also utilized a direct injection technique and direct sorption of the compounds on Tenax for comparative purposes.

The protocol procedure employs a purge and trap device such as a Tekmar Liquid Sample Concentrator for the volatile organics. Typically, five milliliters of a water sample are purged with helium for 12 minutes. The purged organics are trapped on a Tenax®-silica gel trap at room temperature. The species are desorbed by rapidly heating the trap to 180°C.

TABLE A-2. SUMMARY OF METHODS UTILIZED FOR THE ANALYSIS OF ORGANIC PRIORITY POLLUTANTS

API Refinery Designation	Volatile				Base/Neutral Extract				Acidic Extract			
	EPA	Radian	Company	Other	EPA	Radian	Company	Other	EPA	Radian	Company	Other
1	A	--	--	--	A	--	--	--	A	--	--	--
2	A	A	B	--	A	A	C	--	A	A	--	--
3	A	--	--	--	A	--	--	--	A	--	--	--
4	A	--	--	--	A	--	--	--	A	--	--	--
5	A	--	B	A	A	--	D	A	A	--	E	A
6	A	--	B	--	A	--	A,C	--	A	--	A	--
7	--	A	A	--	--	A	A	C	--	A	A	--
8	--	--	--	--	--	--	--	--	--	--	--	--
9	--	A	B	--	--	A	C	--	--	A	--	--
10	--	--	--	--	--	--	--	--	--	--	--	--
11	--	A	--	--	--	A	--	--	--	A	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	A	--	--	--	A	--	--	--
14	--	--	--	--	A	--	--	--	A	--	--	--
15	--	--	--	--	A	--	--	--	A	--	--	--
16	--	--	--	--	A	--	--	--	A	--	--	--
17	--	--	--	--	A	--	--	--	A	--	--	--

Method: A GC/MS analysis (EPA protocol).
B GC analysis using specific detectors.
C GC-UV procedure for PNA's.
D HPLC procedure for PNA's.
E HPLC procedure for alkyl phenols.

Analysis of the desorbed organics is then performed by GC/MS utilizing a Carbopack® - Carbowax® chromatographic column. Analysis for the volatile species is then accomplished by the measurement of characteristic parent or fragment ion intensities which maximize at known retention times as described in the EPA Protocol. This procedure was employed by MRI, Radian, Spectrix, and Shell for their analysis of the Volatile species. The only documented change from the protocol method was by MRI who utilized deuterated chloroform as the internal standard for their analyses.

Mobil performed analysis for volatile organics by conventional gas chromatography utilizing the Tekmar apparatus for the purge and trap portion of the protocol procedure. An SP-2100/Carbowax® column was employed for the analysis with detection of the halogenated compounds with a microcoulometric detector and the remaining volatile hydrocarbons by a flame ionization detector.

Texaco (PARL) employed a Chromalytics® Model 1047 liquid concentrator with a Tenax® trap to purge and trap the volatile organics. Analysis was then performed by gas chromatography utilizing a flame ionization detector for the hydrocarbons and a Hall electrolytic detector for the halogenated species. The hydrocarbon analyses were carried out on a TCEP chromatographic column while a Porapak® Q column was utilized to separate the halogenated species.

Exxon utilized the "Bellar" technique for the halogenated species and three different procedures for the hydrocarbons. The "Bellar" procedure is a purge and trap method utilizing Chromosorb® 103 as the sorbent[1]. Detection of the desorbed compounds was achieved with a microcoulometric detector. An OV-101 chromatographic column was employed for this analysis. Exxon analyzed the remaining volatile hydrocarbons by three techniques, the Grob method of adsorption on activated carbon with head space stripping[4,5,6] a direct injection of the water sample into the mass spectrometer

and a Tenax® desorption method in which the volatile compounds were directly sorbed on the Tenax® by pulling 100 milliliters of water through the tube[8]. Analysis in these three methods was performed by conventional gas chromatography with flame ionization detection and employing an OV-100 column.

2.2 Analysis of Liquid/Liquid Extractable Organics

Liquid/liquid extractable organics are defined in the EPA Protocol as "those unambiguous Priority Pollutants associated with the Consent Decree, that are solvent extractable and amenable to gas chromatography." The protocol procedure employs a liquid/liquid extraction procedure to separate these compounds into two classes: acid and base/neutral. These extracts are obtained by first adjusting the pH of two liters of the sample to pH>12. The basic and neutral compounds are then removed through extraction with methylene chloride. Acidic compounds are removed from the sample through methylene chloride extraction after the pH is adjusted to below pH 2. After concentration, these extracts are analyzed by GC/MS for the compounds of interest. Typically, the base/neutral extractables are chromatographed on SP-2250 and the acid extractables on Tenax® GC. As in the analysis of the volatile species, qualitative and quantitative analysis is performed by the measurement of the ion intensities of selected parent or fragment ions.

The protocol procedure was employed by five laboratories for the analysis of the liquid/liquid extractable organic Priority Pollutants. These laboratories were MRI, RETA, Radian, Spectrix, and Mobil. There were some slight variations from the protocol procedure employed by various laboratories. Table A-3 summarizes the volume of sample extracted by the various analytical participants. Radian utilized an OV-17 capillary column for the analysis of the base/neutral extracts from one refinery[2] while Mobil

TABLE A-3. COMPARISON OF EXTRACTION PROCEDURES EMPLOYED FOR THE ANALYSIS OF THE LIQUID/LIQUID EXTRACTABLE ORGANICS

Laboratory	Amount of Sample Extracted	Sample Bottle Rinsed with CH_2Cl_2
MRI[1]	2ℓ	No
RETA[1]	2ℓ	No
Radian	3-3.5ℓ[2]	Yes
Spectrix	1ℓ	No
Company Refinery 6	2ℓ	No
Company Refinery 7	1ℓ	No

[1]Sample extracted by RSKERL.

[2]Entire contents of bottle were extracted.

employed an SE-30 capillary column for both the base/neutral and acid extracts.

Additional analyses were performed by three other laboratories, Exxon, Mobil, and Texaco, for selected compounds. Exxon analyzed samples from Refineries, 2, 7, and 9 for polynuclear aromatic hydrocarbons by their GC-UV method[2,3,7,9]. After initial addition of 14C labeled PNAs as internal standards, a multi-step liquid/liquid extraction procedure using methylene chloride and dimethyl sulfoxide (DMSO) followed by analysis by gas chromatography with measurement of individual PNAs by ultraviolet adsorption. This procedure was also employed by Mobil in addition to their GC/MS analysis.

Texaco employed two high pressure liquid chromatography (HPLC) methods for the analysis of polynuclear aromatic hydrocarbons and phenols. Polynuclear aromatic hydrocarbons were analyzed by separating the PNA-containing fraction by thin-layer chromatography and then extracting that fraction with ether/methanol. Analysis of this extract was performed on a micro-porous chemically bonded octadecyl silane-type reverse phase column with detection by UV. The absorption of each peak was measured at two different wavelengths. Analysis of phenol and the cresol isomers was performed by a direct injection of the water sample into the HPLC. The same type column and detector system utilized for the PNA analysis was employed for the phenol analysis.

2.3 Special Studies

Radian performed several studies to investigate the protocol extraction and analysis procedure. These studies involved the addition of known amounts of the Priority Pollutants to duplicate water samples and then proceeding through the protocol procedure. The additions were made by dissolving the compounds in methanol before addition to the samples. A portion of the base/

neutral extracts from one of the samples was also given to MRI for comparative purposes. The results from the recovery studies are shown in Table A-4 and data from the interlaboratory comparison is given in Table A-5.

TABLE A-4. RECOVERY OF LIQUID/LIQUID EXTRACTABLE ORGANICS FROM REFINERY FINAL EFFLUENTS[1]

Compound	Initial Concentration (ppb)[2]	Spiked Concentration (ppb)[3]	Total Found (ppb)	Percent Recovery
Recovery Study 1 - Refinery 7[4]				
Naphthalene	<1	74	19	26
Fluorene	<1	54	51	94
Phenanthrene/Anthracene[6]	<1	78	88	113
Pyrene	<1	33	24	73
Di-n-butyl phthalate	32	140	420	300
bis(2-Ethylhexyl) phthalate	15	220	194	88
Phenol	<1	120	51	42
2-Chlorophenol	<1	84	76	90
Recovery Study 2 - Refinery 7[4]				
Naphthalene	<1	210	170	81
Fluorene	<1	160	170	106
Phenanthrene/Anthracene[6]	<1	220	230	104
Pyrene	<1	95	75	79
Phenol	<1	330	150	45
2-Chlorophenol	<1	240	160	67
Di-n-butyl phthalate	6	380	96	25
bis(2-Ethylhexyl) phthalate	5	610	540	89
Recovery Study 3 - Refinery 7[5]				
Naphthalene	<1	210	210	100
Fluorene	<1	160	170	110
Phenanthrene/Anthracene[6]	<1	220	200	91
Pyrene	<1	95	110	116
Phenol	<1	330	140	42
2-Chlorophenol	<1	240	99	41
Di-n-butyl phthalate	6	380	210	55
bis(2-Ethylhexyl) phthalate	5	610	470	77
Recovery Study 4 - Refinery 9[4]				
Naphthalene	N.D.	4.6	2.1	46
Fluorene	.6	5.1	2.5	49
Phenanthrene/Anthracene[6]	N.D.	5.0	3.5	70
Pyrene	1.9	7.3	3.5	48
Butyl benzyl phthalate	N.D.	6.2	0.4	6.5
Phenol	1.9	8.5	5.8	68
2-Chlorophenol	N.D.	3.6	3.3	92
Recovery Study 5 - Refinery 9[4]				
Naphthalene	N.D.	18	12	67
Fluorene	.6	19	16	84
Phenanthrene/Anthracene[6]	N.D.	20	15	75
Pyrene	1.9	23	18	78
Butyl benzyl phthalate	N.D.	25	1	4
Phenol	1.9	29	16	55
2-Chlorophenol	N.D.	14	13	93

[1]All extractions and analyses performed by Radian.

[2]Initial concentration as determined from the previous analysis by Radian of a duplicate sample.

[3]Sum of initial concentration and added spike.

[4]Manual extraction.

[5]Continuous liquid/liquid extraction.

[6]Spike was phenanthrene

TABLE A-5. INTERLABORATORY ANALYSIS[1]

Compound	Calculated Concentration (ppb)[2]	Concentration Found, ppb	
		MRI	Radian
Naphthalene	74	N.D.	19
Fluorene	54	66	51
Phenanthrene/Anthracene[3]	78	40	88
Pyrene	33	4	24
Di-n-butyl phthalate	140	194	420
bis(2-Ethylhexyl) phthalate	220	69	190

[1]Refinery 7.

[2]Concentration in sample based on the first analysis by Radian plus the concentration of the spike.

[3]Spike was phenanthrene.

3.0 ELEMENTAL ANALYSIS METHODOLOGY

Trace element analyses were performed on plant samples by different organizations during the study including:

12 plants - RSKERL (Robert S. Kerr Environmental Research Laboratory)
5 plants - RETA (Ryckman, Edgerley, Tomlinson, and Associates)
3 plants - Radian Corporation
8 plants - Various Company Laboratories

Information concerning the methodology used by each organization is not available. However, methodology provided has been assembled for presentation in Table A-6.

The methodology recommended for Priority Pollutant elemental analysis is from EPA's "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, March, 1977." The methodology is divided into two areas: sample preparation and analysis. Figure A-1 provides a schematic of the analysis protocol.

The element analysis is divided into three groups:

- cold vapor analysis - Hg
- flame AA analysis - Be, Cd, Cr, Cu, Ni, Pb, Zn
- flameless AA analysis - Ag, As, Sb, Se, Ti.

Analysis by flameless AA is required for any element not detected by flame AA.

TABLE A-6. SUMMARY OF METHODS UTILIZED FOR THE ANALYSIS OF TRACE ELEMENTS

API Refinery Designation	EPA	Radian	Company
1	A	--	--
2	A	B	C,E
3	A	--	--
4	A	--	C
5	A	--	D
6	A	--	D
7	A	B	D
8	A	--	D
9	A	B	--
10	A	--	--
11	A	--	E
12	A	--	--
13	D	--	--
14	D	--	--
15	D	--	--
16	D	--	C
17	D	--	--

Notes:

A: Flame AA only.

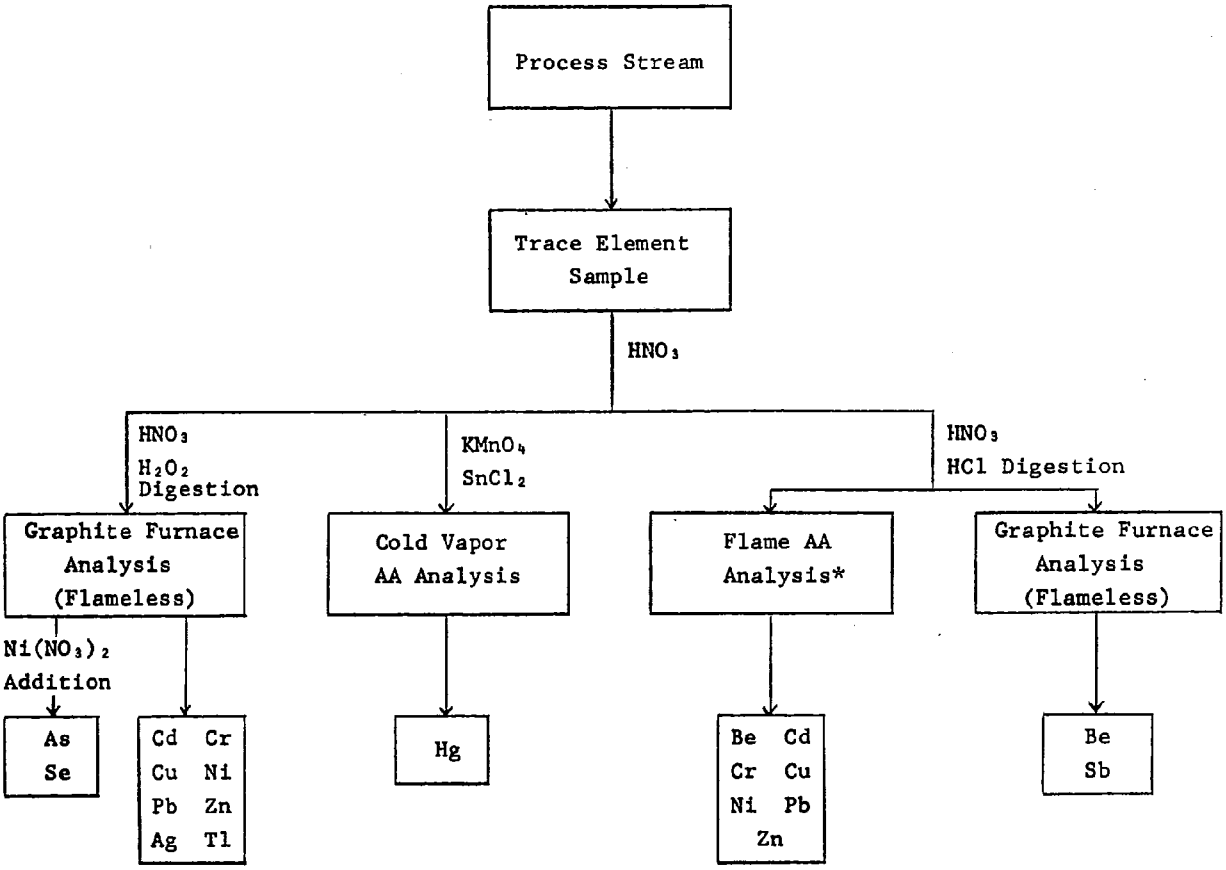
B: EPA Protocol with intensive sample digestion.

C: Total chromium by Standard Methods procedure.

D: AA procedure (both flame and flameless).

E: Procedure not documented; probably AA.

FIGURE A-1. ELEMENT ANALYSIS PROTOCOL



*By Flame Analysis unless concentration is less than specified value.

Be - 20 µg/ℓ	Cr - 200 µg/ℓ	Ni - 100 µg/ℓ
Cd - 20 µg/ℓ	Cu - 50 µg/ℓ	Pb - 300 µg/ℓ
Zn - 20 µg/ℓ		

3.1 Mercury

Mercury was determined by cold vapor flameless atomic absorption as defined by EPA's "Methods for Chemical Analysis of Water and Wastes, 1974."

3.2 Total Trace Elements

Trace elements were determined using both flame and flameless atomic absorption spectrophotometry as specified by EPA. Sample preparation recommendations by the EPA's "Sampling and Analysis for Screening of Industrial Effluents for Priority Pollutants, March, 1977," are not rigidly defined for flameless analyses:

- Flame analysis -- EPA, "Methods of Chemical Analysis of Water and Wastes, 1974," page 83, paragraph 4.1.4;
- Flameless (except Sb and Be) -- "Atomic Absorption Newsletter," Number 14, page 111 (1975);
- Flameless Sb and Be -- EPA, "Methods of Chemical Analysis of Water and Wastes, 1974," page 83, paragraph 4.1.4; and
- Alternate digestion procedure for Flameless Atomic Absorption preparation -- EPA, "Methods of Chemical Analysis of Water and Wastes, 1974," page 83, paragraph 4.1.4.

Therefore, sample preparation procedure may differ among laboratories. Radian deviated from the EPA recommended procedure.

Radian employed a digestion technique that provided for the dissolution of all suspended solids. This initial digestive procedure, based on the works of Theodore Rainsat of the National Bureau of Standards, consisted of an initial filtration and complete dissolution of suspended solids with a mixture of nitric, hydrofluoric, and perchloric acids prior to the application of the EPA procedure. Although more time consuming, this digestive procedure provided complete dissolution of siliceous materials. A comparison of the EPA procedure with and without the initial procedure confirmed good agreement of the two procedures, as shown in Table A-7.

3.3 Special Studies

In an effort to evaluate matrix interference in graphite furnace analysis, Radian added known amounts of each element to the sample for comparative analysis. Table A-8 lists the results of the spiking studies.

TABLE A-7. COMPARISON OF RADIAN AND EPA DIGESTION PROCEDURES IN THE ANALYSIS OF A PETROLEUM REFINERY FINAL EFFLUENT[1] (PPB)

Element	Radian Digestion Procedure	EPA Protocol Digestion Procedure
Ag	7	9
As	4	5
Be	0.5	0.5
Cd	0.3	0.3
Cr	96	100
Cu	8	6
Hg	0.2	0.1
Ni	12	20
Pb	2	1
Sb	23	15
Se	18	20
Tl	5	5
V	1600	1600
Zn	24	15

[1]Refinery 7.

TABLE A-8. SPIKING STUDIES - ELEMENTAL ANALYSIS

Element	Refinery 2				Refinery 7				Refinery 9			
	Concentration, ppb			Percent Recovery	Concentration, ppb			Percent Recovery	Concentration, ppb			Percent Recovery
	Initial	Spike	Found		Initial	Spike	Found		Initial	Spike	Found	
Zinc	55	100	250	161	82	500	720	124	27	250	280	101
Chromium	110	40	150	100	46	50	140	146	94	100	190	98
Copper	130	33	170	104	16	100	130	112	52	100	130	86
Lead	6.6	5.0	21	181	5.3	5.0	18	175	3	100	63	61
Beryllium	0.2	1.7	1.9	100	0.7	2.0	3.5	130	<.1	1	.7	70
Antimony	5.3	10	20	131	68	100	220	131	36	50	36	42
Thallium	4.8	50	32	58	9.5	50	75	126	<2	100	48	48
Nickel	3.4	10	13	97	3.6	10	14	103	2.1	25	21	77
Arsenic	22	50	84	117	16	50	62	94	14	100	120	105
Selenium	11	5	15	94	15	50	30	46	74	100	130	75
Silver	1.3	1.7	5.8	193	0.8	2.0	3.0	107	4.2	5	9	98
Cadmium	1.1	2.0	3.3	106	0.8	2.0	3.0	107	1.1	10	12.6	114
Mercury	0.5	0.05	0.5	91	0.4	0.05	0.5	111	0.8	5	2	34

4.0 ANALYTICAL RESULTS

A detailed summary of all EPA and API analyses conducted is presented in Tables A-9 through A-11. These tables outline the total number of analyses conducted and the frequency of detection for each of the Priority Pollutants.

The actual numerical results from all laboratories are summarized in Tables A-12 through A-51. These tables are organized by refinery using the API designated numbers and subdividing into volatile organics, liquid/liquid extractable organics for Refineries 8, 10, 12, 13, 14, 15, 16, and 17, or for liquid/liquid extractable organics from Refineries 8, 10, and 12.

The sample date designations are:

1 - sample from first day of sampling,
2 - sample from second day of sampling,
3 - sample from third day of sampling, and
6 - composite sample from Days 1, 2, and 3.

Only those Priority Pollutants detected by at least one laboratory at one or more locations in the refinery are listed in the data tables, A-12 through A-51.

TABLE A-9. SUMMARY OF ANALYSES FOR THE VOLATILE ORGANIC PRIORITY POLLUTANTS FOR THE PETROLEUM REFINING INDUSTRY.[1] - EPA AND API DATA -

	INTAKE WATERS				WASTEWATER FEEDS TO BIOTREATMENT				FINAL EFFLUENTS			
Compound	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]
Chloromethane	9	1	21	1	9	1	31	2	9	1	27	1
Dichlorodifluoromethane	9	0	21	0	9	0	31	0	9	0	27	0
Bromomethane	9	0	21	0	9	1	31	1	9	0	27	0
Vinyl chloride	9	0	21	0	9	0	31	0	9	0	27	0
Chloroethane	9	0	21	0	9	0	31	0	9	0	27	0
Methylene chloride	9	8	25	23	9	8	31	30	9	8	27	20
Trichlorofluoromethane	9	0	21	0	9	0	31	0	9	0	27	0
1,1-Dichloroethylene	9	0	21	0	9	1	31	1	9	1	27	1
1,1-Dichloroethane	9	1	21	1	9	1	31	3	9	1	27	3
trans-1,2-Dichloroethylene	9	1	21	3	9	2	31	2	9	0	27	0
Chloroform	9	5	21	9	9	6	31	24	9	5	27	13
1,2-Dichloroethane	9	2	20	4	9	4	31	10	9	3	27	7
1,1,1-Trichloroethane	9	5	25	12	9	3	31	8	9	2	27	6
Carbon tetrachloride	9	2	21	4	9	1	31	4	9	1	27	3
Bromodichloroethane	9	1	21	3	9	3	31	6	9	1	27	3
1,2-Dichloropropane	9	1	21	2	9	2	31	4	9	1	27	2
trans-1,3-Dichloropropene	9	0	21	0	9	2	31	2	9	1	27	1
Trichloroethylene	9	4	21	6	9	4	31	8	9	4	27	7
Dibromochloromethane	9	0	21	0	9	1	31	1	9	0	27	0
cis-1,3-Dichloropropene	9	0	21	0	9	1	31	1	9	0	27	0
1,1,2-Trichloroethane	9	0	21	0	9	0	31	0	9	0	27	0
Benzene	9	6	21	13	9	8	28	26	9	5	23	13
Bromoform	9	0	21	0	9	1	31	2	9	0	27	0
1,1,2,2-Tetrachloroethene	9	2	21	2	9	3	31	8	9	1	27	1
1,1,2,2-Tetrachloroethane	9	0	21	0	9	1	31	2	9	0	27	0
Toluene	9	6	21	13	9	8	28	26	9	5	23	14
Chlorobenzene	9	0	21	0	9	0	31	0	9	0	27	0
Ethylbenzene	9	6	22	14	9	7	28	24	9	4	23	13
Acrolein	9	0	19	0	9	1	26	1	9	0	20	0
Acrylonitrile	9	0	21	0	9	0	31	0	9	0	27	0

[1]Number of refineries where the pollutant was detected by one of the laboratories.
[2]Does not include duplicate determinations.

TABLE A-10. SUMMARY OF ANALYSES FOR THE LIQUID-LIQUID EXTRACTABLE ORGANIC PRIORITY POLLUTANTS FOR THE PETROLEUM REFINING INDUSTRY.[1] - EPA AND API DATA -

Compound	INTAKE WATERS				WASTEWATER FEEDS TO BIOTREATMENT				FINAL EFFLUENTS			
	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]
1,3-Dichlorobenzene	14	0	22	0	14	0	28	0	14	0	20	0
1,4-Dichlorobenzene	14	1	22	1	14	0	28	0	14	0	20	0
Hexachloroethane	14	0	22	0	14	0	28	0	14	0	20	0
1,2-Dichlorobenzene	14	1	22	1	14	0	28	0	14	0	20	0
bis(2-Chloroisopropyl)ether	14	0	18	0	14	0	28	0	14	0	20	0
Hexachlorobutadiene	14	0	16	0	14	0	26	0	14	0	18	0
1,2,4-Trichlorobenzene	14	0	17	0	14	0	28	0	14	0	20	0
Naphthalene	14	5	20	5	14	11	30	20	14	4	20	4
bis(2-Chloroethyl)ether	14	0	17	0	14	0	27	0	14	0	20	0
Hexachlorocyclopentadiene	14	0	15	0	14	0	25	0	14	0	18	0
Nitrobenzene	14	0	16	0	14	0	26	0	14	0	18	0
bis(2-Chloroethoxy)methane	14	0	17	0	14	0	27	0	14	0	20	0
2-Chloronaphthalene	14	0	16	0	14	0	26	0	14	0	18	0
Acenaphthylene	14	3	19	3	14	3	30	5	14	2	21	2
Acenaphthene	14	5	20	5	14	6	30	9	14	3	21	3
Isophorone	14	0	17	0	14	0	27	0	14	0	17	0
Fluorene	14	1	20	1	14	7	21	10	14	1	22	1
2,6-Dinitrotoluene	14	0	16	0	14	0	26	0	14	0	18	0
1,2-Diphenylhydrazine	14	0	15	0	14	0	25	0	14	0	17	0
2,4-Dinitrotoluene	14	0	16	0	14	0	26	0	14	0	18	0
n-Nitrosodiphenylamine	14	0	16	0	14	1	26	1	14	0	17	0
Hexachlorobenzene	14	0	16	0	14	0	26	0	14	0	18	0
4-Bromophenyl phenyl ether	14	0	16	0	14*	0	26	0	14	0	18	0
Phenanthrene/Anthracene	14	6	18	7	14	12	25	19	14	3	18	3
Phenanthrene	3	0	4	0	4	3	5	3	4	0	4	0
Anthracene	3	0	4	0	4	1	5	1	4	0	4	0
Dimethyl phthalate	14	1	16	1	14	0	25	0	14	1	18	1
Diethyl phthalate	14	5	16	5	14	5	25	5	14	5	17	5
Fluoranthene	14	3	22	4	14	9	26	16	14	4	22	4
Pyrene	14	5	22	6	14	9	25	19	14	7	21	10
Di-n-butyl phthalate	14	8	16	8	14	4	25	5	14	6	17	6
Endosulfan sulfate	14	0	15	0	14	0	26	0	14	0	17	0
Benzidine	14	0	16	0	14	0	26	0	14	0	18	0
Butyl benzyl phthalate	14	1	15	1	14	1	25	1	14	0	18	0
Chrysene/Benz(a)anthracene	14	1	16	2	14	6	25	10	14	3	17	4
Chrysene	3	1	3	1	3	6	4	10	3	4	3	4
bis(2-Ethylhexyl)phthalate	14	10	17	10	14	9	25	15	14	9	17	9
Benz(a)anthracene	4	1	5	1	4	3	5	3	4	2	4	2
Benzo(b)/(k)fluoranthene	14	1	17	1	14	1	26	1	14	1	18	1
Benzo(b)fluoranthene	3	0	3	0	3	1	4	1	3	0	3	0
Benzo(k)fluoranthene	3	0	3	0	3	1	4	1	3	0	3	0
Benzo(a)pyrene	14	4	21	5	14	4	31	7	14	4	22	7
Indeno(1,2,3-c,d)pyrene	14	1	19	1	14	2	30	2	14	0	22	0
Dibenzo(a,h)anthracene	14	0	18	0	14	2	30	2	14	0	21	0
Benzo(g,h,i)perylene	14	1	22	1	14	4	31	4	14	1	22	1
n-Nitrosodimethylamine	14	0	15	0	14	0	26	0	14	0	18	0
n-Nitrosodi-n-propylamine	14	0	15	0	14	0	26	0	14	0	18	0
4-Chloro-phenyl phenyl ether	14	0	15	0	14	0	26	0	14	0	18	0
Endrin aldehyde	14	0	15	0	14	0	26	0	14	0	18	0
3,3'-Dichlorobenzidine	14	0	15	0	14	0	26	0	14	0	18	0
2,3,7,8-Tetrachlorodibenzo-p-dioxin	14	0	15	0	14	0	26	0	14	0	18	0
bis(Chloromethyl)ether	14	0	15	0	14	0	29	0	14	0	18	0
Phenol	14	4	19	4	14	13	27	25	14	2	18	2
2-Chlorophenol	14	0	15	0	14	1	25	1	14	0	17	0
2,4-Dimethylphenol	14	1	18	1	14	8	27	14	14	3	17	3
2-Nitrophenol	14	1	16	1	14	0	26	0	14	0	17	0
2,4-Dichlorophenol	14	1	17	1	14	1	27	1	14	0	18	0
p-Chloro-m-cresol	14	0	15	0	14	1	25	2	14	1	17	1
2,4,6-Trichlorophenol	14	0	16	0	14	0	26	0	14	0	18	0
2,4-Dinitrophenol	14	0	16	0	14	0	26	0	14	0	17	0
4-Nitrophenol	14	1	15	1	14	0	26	0	14	0	18	0
4,6-Dinitro-o-cresol	14	2	15	2	14	0	26	0	14	1	17	1
Pentachlorophenol	14	1	16	1	14	2	26	2	14	0	18	0

[1]Number of refineries where the pollutant was detected by one of the laboratories.
[2]Does not include duplicate determinations.

TABLE A-11. SUMMARY OF ANALYSES FOR THE TRACE ELEMENT PRIORITY POLLUTANTS FOR THE PETROLEUM REFINING INDUSTRY[1]

- EPA AND API DATA -

	INTAKE WATERS				WASTEWATER FEEDS TO BIOTREATMENT				FINAL EFFLUENTS			
Compound	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]	Number of Refineries Tested	Frequency of Detection[1]	Number of Determinations[2]	Number of Reported Values[2]
Zinc	17	16	31	29	17	17	76	73	17	17	37	36
Chromium	17	14	39	27	17	16	81	81	17	16	41	39
Copper	17	14	31	21	17	16	48	42	17	14	31	22
Lead	17	14	39	20	17	14	41	42	17	12	39	19
Beryllium	17	2	29	4	17	3	40	7	17	3	29	6
Antimony	17	6	29	10	17	8	40	15	17	7	29	13
Thallium	17	2	40	2	17	5	72	13	17	5	40	9
Nickel	17	9	34	15	17	12	46	27	17	9	36	19
Arsenic	17	8	30	11	17	12	43	25	17	8	35	15
Selenium	17	10	36	20	17	10	76	55	17	11	44	30
Silver	17	4	31	5	17	5	42	8	17	5	31	6
Cadmium	17	4	31	7	17	4	46	13	17	6	34	8
Mercury	16	10	48	18	16	10	67	31	16	10	49	15

[1]Number of refineries where the pollutant was detected by one of the laboratories.
[2]Does not include duplicate determinations.

TABLE A-12 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 1, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R4)				WASTEWATER FEED TO BIOTREATMENT (R5)			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
METHYLENE CHLORIDE	(6) 6	40 Z	-	-	-	Q(100)Z	-	-	-	50 Z	-	-	-
CHLOROFORM	(11) 6	ND(<10)	-	-	-	10	-	-	-	D(<10)	-	-	-
1,2-DICHLOROETHANE	(12) 6	ND(<10)	-	-	-	ND(<10)	-	-	-	D(<10)A	-	-	-
BROMODICHLOROMETHANE	(15) 6	ND(<10)	-	-	-	ND(<10)	-	-	-	D(<10)A	-	-	-
BENZENE	(22) 6	ND(<10)	-	-	-	Q(100)	-	-	-	Q(100)	-	-	-
TOLUENE	(26) 6	ND(<10)	-	-	-	Q(100)	-	-	-	Q(100)	-	-	-
ETHYLBENZENE	(28) 6	ND(<10)	-	-	-	Q(100)	-	-	-	Q(100)	-	-	-
ACROLEIN	(29) 6	ND(<10)	-	-	-	ND(<10)	-	-	-	D(<10)A	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
A - POSSIBLE IDENTIFICATION
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION

TABLE A-12 (CONTINUED) CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 1, UG/L

PARAMETER	SAMPLE DATE	FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER
METHYLENE CHLORIDE	(6) 6	60 Z	-	-	-
CHLOROFORM	(11) 6	ND(<10)	-	-	-
1,2-DICHLOROETHANE	(12) 6	ND(<10)	-	-	-
BROMODICHLOROMETHANE	(15) 6	ND(<10)	-	-	-
BENZENE	(22) 6	ND(<10)	-	-	-
TOLUENE	(26) 6	ND(<10)	-	-	-
ETHYLBENZENE	(28) 6	ND(<10)	-	-	-
ACROLEIN	(29) 6	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION

TABLE A-13 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 1, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R4)				WASTEWATER FEED TO BIOTREATMENT (R5)			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	1	-	-	-	500	-	-	-	284	-	-	-
ACENAPHTHYLENE	(14) 6	.2	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ACENAPHTHENE	(15) 6	29	-	-	-	ND(<1)	-	-	-	3000	-	-	-
FLUORENE	(17) 6	1	-	-	-	270	-	-	-	304	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	1.2 H	-	-	-	234 H	-	-	-	ND(<1)	-	-	-
FLUORANTHENE	(29) 6	.2	-	-	-	ND(<1)	-	-	-	8.5	-	-	-
PYRENE	(30) 6	.3	-	-	-	ND(<1)	-	-	-	7	-	-	-
CHRYSENE	(36) 6	ND(<1)	-	-	-	20	-	-	-	1.6	-	-	-
PHENOL	(53) 6	ND(<50)	-	-	-	Q(100)	-	-	-	Q(100)	-	-	-
2-4-DIMETHYLPHENOL	(55) 6	ND(<50)	-	-	-	Q(100)	-	-	-	Q(100)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-13 (CONTINUED) CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 1, UG/L

PARAMETER	SAMPLE DATE	FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	1	-	-	-
ACENAPHTHYLENE	(14) 6	ND(<1)	-	-	-
ACENAPHTHENE	(15) 6	6	-	-	-
FLUORENE	(17) 6	ND(<1)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	8 H	-	-	-
FLUORANTHENE	(29) 6	D(<.1)	-	-	-
PYRENE	(30) 6	D(<.1)	-	-	-
CHRYSENE	(36) 6	3	-	-	-
PHENOL	(53) 6	ND(<50)	-	-	-
2-4-DIMETHYLPHENOL	(55) 6	ND(<50)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-14 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 1, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R4)				WASTEWATER FEED TO BIOTREATMENT (R5)			
		EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1) 6	120	-	-	-	370	-	-	-	290	-	-	-
CHROMIUM	(2) 6	30	-	-	-	290	-	-	-	870	-	-	-
COPPER	(3) 6	20	-	-	-	180	-	-	-	50	-	-	-
LEAD	(4) 6	40	-	-	-	45	-	-	-	17	-	-	-
BERYLLIUM	(5) 6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6) 6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7) 6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8) 6	21	-	-	-	70	-	-	-	16	-	-	-
ARSENIC	(9) 6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SELENIUM	(10) 6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SILVER	(11) 6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12) 6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13) 1	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
	2	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
	3	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-14 (CONTINUED) CONCENTRATION OF TRACE ELEMENTS AT REFINERY 1, UG/L

PARAMETER		SAMPLE DATE	FINAL EFFLUENT			
			EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1)	6	140	-	-	-
CHROMIUM	(2)	6	190	-	-	-
COPPER	(3)	6	39	-	-	-
LEAD	(4)	6	ND(<15)	-	-	-
BERYLLIUM	(5)	6	ND(<3)	-	-	-
ANTIMONY	(6)	6	ND(<25)	-	-	-
THALLIUM	(7)	6	ND(<15)	-	-	-
NICKEL	(8)	6	15	-	-	-
ARSENIC	(9)	6	ND(<20)	-	-	-
SELENIUM	(10)	6	ND(<20)	-	-	-
SILVER	(11)	6	ND(<5)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-
MERCURY	(13)	1	ND(<.5)	-	-	-
		2	ND(<.5)	-	-	-
		3	ND(<.5)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-15 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 2, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (C1)			
			EPA MRI	RADIAN	COMPANY (2)	OTHER	EPA MRI	RADIAN	COMPANY (2)	OTHER	EPA MRI	RADIAN	COMPANY (2)	OTHER
CHLOROMETHANE	(1)	1	–	–	ND(<1)	–	–	ND(<10)	ND(<1)	–	–	ND(<10)	–	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	ND(<10)	–	–
		3	–	–	D(<.5)	–	–	ND(<10)	ND(<1)	–	–	ND(<10)	–	–
		6	ND(<100)	ND(<10)	–	–	ND(<100)	–	–	–	G(100)	ND(<10)	17000	–
BROMOMETHANE	(3)	1	–	–	ND(<1)	–	–	ND(<5)	ND(<1)	–	–	ND(<5)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	ND(<5)	ND(<1)	–
		3	–	–	ND(<1)	–	–	ND(<5)	ND(<1)	–	–	ND(<5)	ND(<1)	–
		6	ND(<10)	ND(<5)	–	–	ND(<10)	–	–	–	D(<10)A	ND(<5)	–	–
METHYLENE CHLORIDE	(6)	1	–	–	.6 CE	–	–	30	1 CE	–	–	150	D(<1)	–
		2	–	–	.4 E	–	–	–	1	–	–	190	D(<1)C	–
		3	–	–	.4 E	–	–	300	.9 CE	–	–	60	.5	–
		6	G(100)Z	10	–	–	G(100)Z	–	–	–	G(100)Z	160	–	–
1,1-DICHLOROETHYLENE	(8)	1	–	–	ND(<1)	–	–	ND(<1)	ND(<1)	–	–	ND(<1)	–	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	10	ND(<1)	–
		3	–	–	ND(<1)	–	–	ND(<1)	ND(<1)	–	–	ND(<1)	ND(<1)	–
		6	ND(<10)	ND(<1)	–	–	ND(<10)	–	–	–	ND(<10)	ND(<1)	ND(<1)	–
CHLOROFORM	(11)	1	–	–	ND(<1)	–	–	ND(<.3)	22 C	–	–	9	14	–
		2	–	–	ND(<1)	–	–	–	17	–	–	10	7 C	–
		3	–	–	ND(<1)	–	–	30	21 C	–	–	6	9	–
		6	ND(<10)	ND(<.3)	–	–	15	–	–	–	10	6	–	–
1,2-DICHLOROETHANE	(12)	1	–	–	ND(<1)E	–	–	ND(<5)	14 CE	–	–	ND(<5)	ND(<1)E	–
		2	–	–	ND(<1)E	–	–	–	9 E	–	–	ND(<5)	ND(<1)E	–
		3	–	–	ND(<1)E	–	–	30	51 CE	–	–	ND(<5)	6 E	–
		6	ND(<10)	ND(<5)	–	–	ND(<10)	–	–	–	ND(<10)	ND(<5)	–	–
1,1,1-TRICHLOROETHANE	(13)	1	–	–	ND(<1)	–	–	ND(<.3)	ND(<1)	–	–	ND(<.3)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	10	ND(<1)	–
		3	–	–	ND(<1)	–	–	10	ND(<1)	–	–	6	ND(<1)	–
		6	ND(<10)	2	–	–	ND(<10)	–	–	–	ND(<10)	ND(<.3)	–	–
1,2-DICHLOROPROPANE	(16)	1	–	–	ND(<1)	–	–	ND(<.4)	ND(<1)	–	–	ND(<.4)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	ND(<.4)	ND(<1)	–
		3	–	–	ND(<1)	–	–	ND(<.4)	ND(<1)	–	–	ND(<.4)	ND(<1)	–
		6	ND(<10)	ND(<.4)	–	–	ND(<10)	ND(<.4)	–	–	D(<10)A	ND(<.4)	–	–
TRICHLOROETHYLENE	(18)	1	–	–	ND(<1)	–	–	ND(<.2)	ND(<1)	–	–	ND(<.2)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	ND(<.2)	ND(<1)	–
		3	–	–	ND(<1)	–	–	2	ND(<1)	–	–	2	ND(<1)	–
		6	ND(<10)	ND(<.2)	–	–	ND(<10)	–	–	–	ND(<10)	D(<1)	–	–
DIBROMOCHLOROMETHANE	(19)	1	–	–	ND(<1)	–	–	ND(<.5)	ND(<1)	–	–	ND(<.5)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	ND(<.5)	ND(<1)	–
		3	–	–	ND(<1)	–	–	ND(<.5)	ND(<1)	–	–	ND(<.5)	ND(<1)	–
		6	ND(<10)	ND(<.5)	–	–	107	–	–	–	ND(<10)	–	–	–
BENZENE	(22)	1	–	–	–	–	–	50	–	–	–	50	–	–
		2	–	–	–	–	–	–	–	–	–	40	–	–
		3	–	–	–	–	–	30	–	–	–	10	–	–
		6	ND(<10)	1	3	–	G(100)	–	5000 C	–	90	20	4000 C	–
1,1,2,2-TETRACHLOROETHENE	(24)	1	–	–	ND(<1)	–	–	ND(<.4)	2 C	–	–	ND(<.4)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	1	–	–	ND(<.4)	ND(<1)	–
		3	–	–	ND(<1)	–	–	ND(<.4)	4 C	–	–	ND(<.4)	D(<.5)	–
		6	ND(<10)	ND(<.4)	–	–	ND(<10)	–	–	–	ND(<10)	ND(<.4)	–	–
1,1,2,2-TETRACHLOROETHANE	(25)	1	–	–	ND(<1)	–	–	ND(<.5)	ND(<1)	–	–	ND(<.5)	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	ND(<.5)	ND(<1)	–
		3	–	–	ND(<1)	–	–	2	ND(<1)	–	–	2	ND(<1)	–
		6	ND(<10)	ND(<.5)	–	–	ND(<10)	–	–	–	ND(<10)	ND(<.5)	–	–
TOLUENE	(26)	1	–	–	–	–	–	130	–	–	–	40	–	–
		2	–	–	–	–	–	–	–	–	–	110	–	–
		3	–	–	–	–	–	50	–	–	–	50	–	–
		6	ND(<10)	6	3	–	G(100)	–	9000 C	–	G(100)	50	7000 C	–
ETHYLBENZENE	(28)	1	–	–	–	–	–	70	–	–	–	10	–	–
		2	–	–	–	–	–	–	–	–	–	60	–	–
		3	–	–	–	–	–	100	–	–	–	1	–	–
		6	ND(<10)	2	D(<2)	–	ND(<10)	–	70 C	–	20	30	D(<70)C	–

D(X) – COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
G(X) – COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X
ND(X)– COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
A – POSSIBLE IDENTIFICATION
C – ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
E – MAXIMUM VALUE, REPORTED VALUE MAY INCLUDE OTHER SPECIES WHICH CONTRIBUTE TO THE MEASURED CONCENTRATION
Z – BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION
2 – ORGANOHALIDES BY BELLAR QC METHOD; OTHER VOLATILE SPECIES BY GROB QC METHOD.

TABLE A-15 (CONTINUED) CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY X, UG/L

PARAMETER		SAMPLE DATE	FINAL EFFLUENT EPA MRI	RADIAN	COMPANY (2)	OTHER
CHLOROMETHANE	(1)	1	-	ND(<10)	D(< 5)	-
		2	-	ND(<10)	ND(<1)	-
		3	-	ND(<10)	ND(<1)	-
		6	ND(<10)	-	-	-
BROMOMETHANE	(3)	1	-	ND(<5)	ND(<1)	-
		2	-	ND(<5)	ND(<1)	-
		3	-	ND(<5)	ND(<1)	-
		6	ND(<10)	-	-	-
METHYLENE CHLORIDE	(6)	1	-	D(<5)	1 CE	-
		2	-	D(<5)	.6 E	-
		3	-	D(<5)	5 E	-
		6	ND(<40)Z	-	-	-
1,1-DICHLOROETHYLENE	(8)	1	-	10	ND(<1)	-
		2	-	ND(<1)	ND(<1)	-
		3	-	D(<1)	1	-
		6	ND(<10)	-	-	-
CHLOROFORM	(11)	1	-	ND(< 3)	D(<1)C	-
		2	-	ND(< 3)	D(< 5)	-
		3	-	ND(< 3)	D(< 5)	-
		6	ND(<10)	-	-	-
1,2-DICHLOROETHANE	(12)	1	-	ND(<5)	D(< 5)E	-
		2	-	ND(<5)	D(< 5)E	-
		3	-	ND(<5)	D(< 5)E	-
		6	ND(<10)	-	-	-
1,1,1-TRICHLOROETHANE	(13)	1	-	3	ND(<1)	-
		2	-	2	ND(<1)	-
		3	-	3	ND(<1)	-
		6	ND(<10)	-	-	-
1,2-DICHLOROPROPANE	(16)	1	-	ND(< 4)	ND(<1)	-
		2	-	ND(< 4)	ND(<1)	-
		3	-	ND(< 4)	ND(<1)	-
		6	ND(<10)	-	-	-
TRICHLOROETHYLENE	(18)	1	-	1	ND(<1)	-
		2	-	3	ND(<1)	-
		3	-	ND(< 2)	ND(<1)	-
		6	ND(<10)	-	-	-
DIBROMOCHLOROMETHANE	(19)	1	-	ND(< 5)	ND(<1)	-
		2	-	ND(< 5)	ND(<1)	-
		3	-	ND(< 5)	ND(<1)	-
		6	ND(<10)	-	-	-
BENZENE	(22)	1	-	1	-	-
		2	-	1	-	-
		3	-	30	-	-
		6	6 Z	-	3 C	-
1,1,2,2-TETRACHLOROETHENE	(24)	1	-	ND(< 4)	ND(<1)	-
		2	-	ND(< 4)	ND(<1)	-
		3	-	ND(< 4)	ND(<1)	-
		6	ND(<10)	-	-	-
1,1,2,2-TETRACHLOROETHANE	(25)	1	-	ND(< 5)	ND(<1)	-
		2	-	ND(< 5)	ND(<1)	-
		3	-	ND(< 5)	ND(<1)	-
		6	ND(<10)	-	-	-
TOLUENE	(26)	1	-	3	-	-
		2	-	3	-	-
		3	-	60	-	-
		6	35	-	10 C	-
ETHYLBENZENE	(28)	1	-	1	-	-
		2	-	1	-	-
		3	-	20	-	-
		6	ND(<10)	-	D(<5)C	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
@(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
E - MAXIMUM VALUE, REPORTED VALUE MAY INCLUDE OTHER SPECIES WHICH CONTRIBUTE TO THE MEASURED CONCENTRATION
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION
2 - ORGANOHALIDES BY BELLAR GC METHOD. OTHER VOLATILE SPECIES BY GROB GC METHOD

TABLE A-16 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 2, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (C1)			
		EPA MRI	RADIAN	COMPANY (6)	OTHER	EPA MRI	RADIAN	COMPANY (6)	OTHER	EPA MRI	RADIAN	COMPANY (6)	OTHER
NAPHTHALENE	(8) 6	ND(<1)	ND(<.1)	D(<2)	-	302	450	400 C	-	27	230	D(<50)	-
ACENAPHTHYLENE	(14) 6	ND(<1)	ND(<.1)	D(<2)	-	87	ND(<.1)	D(<50)	-	ND(<1)	ND(<.1)	D(<40)	-
ACENAPHTHENE	(15) 6	ND(<1)	ND(<.1)	D(<2)	-	522	9	200	-	ND(<1)	ND(<.1)	D(<40)	-
FLUORENE	(17) 6	ND(<1)	ND(<.1)	ND(<.4)	-	ND(<1)	30	7 C	-	ND(<1)	ND(<.1)	ND(<.4)	-
PHENANTHRENE/ANTHRACENE	(24) 6	ND(<1)	3 H	-	-	136 H	110 H	-	-	.6 H	2 H	-	-
PHENANTHRENE	(25) 6	-	-	ND(<.2)	-	-	-	28 C	-	-	-	ND(<.01)	-
ANTHRACENE	(26) 6	-	-	ND(<.02)	-	-	-	.1 C	-	-	-	ND(<.2)	-
DIETHYL PHTHALATE	(28) 6	ND(<1)	20	-	-	ND(<1)	2	-	-	ND(<1)	ND(<.4)	-	-
FLUORANTHENE	(29) 6	ND(<1)	ND(<.1)	ND(<.04)	-	7.5	1	1.7 C	-	ND(<1)	.2	.04	-
PYRENE	(30) 6	ND(<1)	.2	ND(<.03)	-	16	3	4.1 C	-	.7	D(<.1)	.06	-
DI-N-BUTYL PHTHALATE	(31) 6	ND(<1)	20	-	-	ND(<1)	10	-	-	ND(<1)	45	-	-
BUTYL BENZYL PHTHALATE	(34) 6	ND(<1)	2	-	-	ND(<1)	ND(<.1)	-	-	ND(<1)	6	-	-
CHRYSENE	(36) 6	ND(<1)	.3	ND(<.02)	-	5.5	9	2 C	-	D(<1)	ND(<.1)	ND(<.02)	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	ND(<1)	8	-	-	ND(<1)	ND(<.1)	-	-	ND(<1)	6	-	-
BENZ(A)ANTHRACENE	(38) 6	ND(<1)	.1	ND(<.01)	-	ND(<1)	ND(<.2)	1.4 C	-	ND(<1)	ND(<.1)	ND(<.04)	-
BENZO(B)/(K)FLUORANTHENE	(39) 6	ND(<1)	ND(<.2)	-	-	ND(<1)	ND(<.2)	-	-	ND(<1)	ND(<.2)	-	-
BENZO(B)FLUORANTHENE	(40) 6	-	-	ND(<.06)	-	-	-	.3 C	-	-	-	ND(<.09)	-
BENZO(K)FLUORANTHENE	(41) 6	-	-	ND(<.1)	-	-	-	.3 C	-	-	-	ND(<.3)	-
BENZO(A)PYRENE	(42) 6	ND(<1)	ND(<.1)	.07	-	ND(<1)	ND(<.1)	.8 C	-	ND(<1)	ND(<.1)	.02	-
INDENO(1,2,3-C,D)PYRENE	(43) 6	ND(<1)	ND(<.2)	ND(<.01)	-	ND(<1)	ND(<.2)	.02 C	-	ND(<1)	ND(<.2)	ND(<.02)	-
DIBENZO(A,H)ANTHRACENE	(44) 6	ND(<1)	ND(<.3)	ND(<.02)	-	ND(<1)	ND(<.3)	.07 C	-	ND(<1)	ND(<.2)	ND(<.03)	-
BENZO(G,H,I)PERYLENE	(45) 6	ND(<1)	ND(<.2)	ND(<.1)	-	ND(<1)	ND(<.2)	.4 C	-	ND(<1)	ND(<.2)	ND(<.2)	-
PHENOL	(53) 6	ND(<50)	ND(<.1)	-	-	G(100)	1300	-	-	40	13	-	-
2-CHLOROPHENOL	(54) 6	ND(<50)	ND(<.1)	-	-	ND(<50)	ND(<.1)	-	-	ND(<50)	1	-	-
2-4-DIMETHYLPHENOL	(55) 6	ND(<50)	ND(<.2)	-	-	71	680	-	-	G(100)	8	-	-
2-NITROPHENOL	(56) 6	ND(<50)	D(<1)	-	-	ND(<50)	ND(<.2)	-	-	ND(<50)	ND(<.3)	-	-
2,4-DICHLOROPHENOL	(57) 6	ND(<50)	ND(<.1)	-	-	ND(<50)	ND(<.1)	-	-	ND(<50)	D(<1)	-	-
P-CHLORO-M-CRESOL	(58) 6	ND(<50)	ND(<.1)	-	-	ND(<50)	ND(<.1)	-	-	10	D(<1)	-	-
4-NITROPHENOL	(61) 6	ND(<50)	4	-	-	ND(<50)	ND(<.3)	-	-	ND(<50)	ND(<.3)	-	-
4,6-DINITRO-O-CRESOL	(62) 6	ND(<50)	D(<1)	-	-	ND(<50)	ND(<.6)	-	-	ND(<50)	ND(<.3)	-	-
PENTACHLOROPHENOL	(63) 6	ND(<50)	D(<1)	-	-	ND(<50)	ND(<.4)	-	-	ND(<50)	D(<1)	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.
6 - NAPHTHALENE, ACENAPHTHALENE, AND ACENAPHTHENE BY GROB GC METHOD; OTHER SPECIES BY GC-UV METHOD.

TABLE A-16 (CONTINUED) CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 2, UG/L

PARAMETER		SAMPLE DATE	FINAL EFFLUENT			
			EPA MRI	RADIAN	COMPANY (6)	OTHER
NAPHTHALENE	(8)	6	ND(<1)	ND(<.1)	4	-
ACENAPHTHYLENE	(14)	6	ND(<1)	ND(<.1)	D(<10)	-
ACENAPHTHENE	(15)	6	ND(<1)	ND(<.1)	40	-
FLUORENE	(17)	6	ND(<1)	ND(<.1)	ND(<.4)	-
PHENANTHRENE/ANTHRACENE	(24)	6	ND(<1)	ND(< 1)H	-	-
PHENANTHRENE	(25)	6	-	-	ND(<.3)	-
ANTHRACENE	(26)	6	-	-	ND(<.02)	-
DIETHYL PHTHALATE	(28)	6	ND(<1)	7	-	-
FLUORANTHENE	(29)	6	ND(<1)	ND(< 1)	.3	-
PYRENE	(30)	6	ND(<1)	D(<.1)	.1	-
DI-N-BUTYL PHTHALATE	(31)	6	ND(<1)	10	-	-
BUTYL BENZYL PHTHALATE	(34)	6	ND(<1)A	ND(<.1)	-	-
CHRYSENE	(36)	6	ND(<1)	ND(<.1)	ND(<.01)	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37)	6	ND(<1)	2	-	-
BENZ(A)ANTHRACENE	(38)	6	ND(<1)	ND(<.2)	ND(<.05)	-
BENZO(B)/(K)FLUORANTHENE	(39)	6	ND(<1)	ND(< 2)	-	-
BENZO(B)FLUORANTHENE	(40)	6	-	-	ND(<.06)	-
BENZO(K)FLUORANTHENE	(41)	6	-	-	ND(<.2)	-
BENZO(A)PYRENE	(42)	6	ND(<1)	ND(<.1)	ND(<.01)	-
INDENO(1,2,3-C,D)PYRENE	(43)	6	ND(<1)	ND(<.2)	ND(<.06)	-
DIBENZO(A,H)ANTHRACENE	(44)	6	ND(<1)	ND(<.3)	ND(<.02)	-
BENZO(G,H,I)PERYLENE	(45)	6	ND(<1)	ND(<.2)	ND(<.1)	-
PHENOL	(33)	6	ND(<1)	ND(<.1)	-	-
2-CHLOROPHENOL	(34)	6	ND(<50)	ND(<.1)	-	-
2-4-DIMETHYLPHENOL	(35)	6	ND(<50)	ND(<.2)	-	-
2-NITROPHENOL	(36)	6	ND(<50)	ND(<.2)	-	-
2,4-DICHLOROPHENOL	(37)	6	ND(<50)	ND(<.1)	-	-
P-CHLORO-M-CRESOL	(38)	6	ND(<50)	ND(<.1)	-	-
4-NITROPHENOL	(61)	6	ND(<50)	ND(<.3)	-	-
4,6-DINITRO-O-CRESOL	(62)	6	ND(<50)	ND(<.6)	-	-
PENTACHLOROPHENOL	(63)	6	ND(<50)	ND(<.4)	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
C(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
A - POSSIBLE IDENTIFICATION
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.
6 - NAPHTHALENE, ACENAPHTHALENE, AND ACENAPHTHENE BY GROB GC METHOD; OTHER SPECIES BY GC-UV METHOD

TABLE A-17 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 2, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (C1)			
			EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1)	6	19	29	-	-	570	1000	-	-	4800	9600	-	-
CHROMIUM	(2)	1	-	-	ND(<)B	-	-	-	900	-	-	-	700	-
		2	-	-	10	-	-	-	120	-	-	-	600	-
		3	-	-	ND(<)B	-	-	-	740	-	-	-	360	-
		6	7	1300	-	-	1400	780	-	-	650	800	-	-
COPPER	(3)	6	ND(<5)	35	-	-	61	39	-	-	13	26	-	-
LEAD	(4)	6	ND(<15)	6.6	-	-	18	19	-	-	ND(<15)	20	-	-
BERYLLIUM	(5)	6	ND(<3)	.4	-	-	ND(<3)	.3	-	-	ND(<3)	.3	-	-
ANTIMONY	(6)	6	ND(<25)	.3	-	-	ND(<25)	2.6	-	-	ND(<25)	.4	-	-
THALLIUM	(7)	6	ND(<15)	15	-	-	ND(<15)	190	-	-	ND(<15)	54	-	-
NICKEL	(8)	6	ND(<15)	1.2	-	-	16	31	-	-	ND(<15)	1.5	-	-
ARSENIC	(9)	6	ND(<20)	15	-	-	ND(<20)	29	-	-	ND(<20)	21	-	-
SELENIUM	(10)	6	ND(<20)	17	-	-	ND(<20)	17	-	-	ND(<20)	15	-	-
SILVER	(11)	6	ND(<5)	.1	-	-	ND(<5)	.2	-	-	ND(<5)	3.1	-	-
CADMIUM	(12)	6	ND(<1)	.3	-	-	ND(<1)	4.1	-	-	ND(<1)	1.7	-	-
MERCURY	(13)	1	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
		2	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
		3	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
		6	-	4	-	-	-	.4	-	-	-	59	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
B - POSSIBLE TYPOGRAPHICAL ERROR IN ORIGINAL DATA
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-17 (CONTINUED) CONCENTRATION OF TRACE ELEMENTS AT REFINERY 2, UG/L

PARAMETER		SAMPLE DATE	FINAL EFFLUENT EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1)	6	35	55	-	-
CHROMIUM	(2)	1	-	-	60	-
		2	-	-	90	-
		3	-	-	80	-
		6	120	110	-	-
COPPER	(3)	6	11	130	-	-
LEAD	(4)	6	ND(<15)	6.6	-	-
BERYLLIUM	(5)	6	ND(<3)	.2	-	-
ANTIMONY	(6)	6	ND(<25)	5.3	-	-
THALLIUM	(7)	6	ND(<15)	4.8	-	-
NICKEL	(8)	6	ND(<15)	3.4	-	-
ARSENIC	(9)	6	ND(<20)	22	-	-
SELENIUM	(10)	6	ND(<20)	11	-	-
SILVER	(11)	6	ND(<5)	1.3	-	-
CADMIUM	(12)	6	ND(<1)	1.1	-	-
MERCURY	(13)	1	ND(<.5)	-	-	-
		2	ND(<.5)	-	-	-
		3	ND(<.5)	-	-	-
		6	-	.5	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-18 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 3, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
METHYLENE CHLORIDE	(6) 6	G(50)	-	-	-	G(50)	-	-	-	G(50)	-	-	-
TRANS-1,2-DICHLOROETHYLENE	(10) 6	ND(<10)	-	-	-	20	-	-	-	ND(<10)	-	-	-
CHLOROFORM	(11) 6	70	-	-	-	D(<5)	-	-	-	D(<5)	-	-	-
BROMODICHLOROMETHANE	(15) 6	ND(<10)	-	-	-	D(<10)A	-	-	-	ND(<10)	-	-	-
BENZENE	(22) 6	ND(<10)	-	-	-	G(100)	-	-	-	ND(<10)	-	-	-
1,1,2,2-TETRACHLOROETHENE	(24) 6	ND(<10)	-	-	-	G(50)	-	-	-	D(<10)	-	-	-
TOLUENE	(26) 6	ND(<10)	-	-	-	G(100)	-	-	-	ND(<10)	-	-	-
ETHYLBENZENE	(28) 6	ND(<10)	-	-	-	G(100)	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
A - POSSIBLE IDENTIFICATION

TABLE A-19 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 3, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<1)	-	-	-	68	-	-	-	ND(<1)	-	-	-
ACENAPHTHYLENE	(14) 6	ND(<1)	-	-	-	4	-	-	-	ND(<1)	-	-	-
ACENAPHTHENE	(15) 6	ND(<1)	-	-	-	37	-	-	-	ND(<1)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	D(<.1)	-	-	-	4.6 H	-	-	-	ND(<1)	-	-	-
DIETHYL PHTHALATE	(28) 6	ND(<1)	-	-	-	12	-	-	-	ND(<1)	-	-	-
DI-N-BUTYL PHTHALATE	(31) 6	.2	-	-	-	1.3	-	-	-	.7	-	-	-
PHENOL	(53) 6	ND(<50)	-	-	-	13	-	-	-	ND(<50)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-20 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 3, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1) 6	ND(<10)	-	-	-	220	-	-	-	30	-	-	-
CHROMIUM	(2) 6	ND(<5)	-	-	-	32	-	-	-	5	-	-	-
COPPER	(3) 6	ND(<5)	-	-	-	17	-	-	-	ND(<5)	-	-	-
LEAD	(4) 6	ND(<15)	-	-	-	64	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5) 6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6) 6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7) 6	ND(<25)B	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8) 6	ND(<15)	-	-	-	23	-	-	-	ND(<15)	-	-	-
ARSENIC	(9) 6	ND(<10)	-	-	-	12	-	-	-	ND(<10)	-	-	-
SELENIUM	(10) 6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
SILVER	(11) 6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12) 6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13) 1	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
	2	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
	3	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
B - POSSIBLE TYPOGRAPHICAL ERROR IN ORIGINAL DATA
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-21 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 4, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
BENZENE	(22) 6	ND(<10)	-	-	-	G(100)	-	-	-	ND(<10)	-	-	-
TOLUENE	(26) 6	ND(<10)	-	-	-	G(100)	-	-	-	ND(<10)	-	-	-
ETHYLBENZENE	(28) 6	ND(<10)	-	-	-	G(100)	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-22 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 4, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	1.8	-	-	-	190	-	-	-	ND(<1)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	D(<.1)H	-	-	-	142 H	-	-	-	ND(<1)H	-	-	-
FLUORANTHENE	(29) 6	ND(<1)	-	-	-	2.5	-	-	-	ND(<1)	-	-	-
PYRENE	(30) 6	ND(<1)	-	-	-	11	-	-	-	7	-	-	-
CHRYSENE	(36) 6	ND(<1)	-	-	-	.1	-	-	-	1.4	-	-	-
BENZO(A)PYRENE	(42) 6	ND(<1)	-	-	-	ND(<1)	-	-	-	2.9	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-23 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 4, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1)	6	33	-	-	-	280	-	-	-	400	-	-	-
CHROMIUM	(2)	3	-	-	ND(<10)	-	-	-	820	-	-	-	1110	-
		6	14	-	-	-	730	-	-	-	1000	-	-	-
COPPER	(3)	6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
LEAD	(4)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5)	6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6)	6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
ARSENIC	(9)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
SELENIUM	(10)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
SILVER	(11)	6	ND(<5)	-	-	-	ND(<5)	-	-	-	15	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
		3	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-24 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 5, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER EPA MRI	INTAKE WATER RADIAN	INTAKE WATER COMPANY (7)	INTAKE WATER OTHER SPECTRIX	WASTEWATER FEED TO BIOTREATMENT EPA MRI	WASTEWATER FEED TO BIOTREATMENT RADIAN	WASTEWATER FEED TO BIOTREATMENT COMPANY (7)	WASTEWATER FEED TO BIOTREATMENT OTHER SPECTRIX	FINAL EFFLUENT EPA MRI	FINAL EFFLUENT RADIAN	FINAL EFFLUENT COMPANY (7)	FINAL EFFLUENT OTHER SPECTRIX
METHYLENE CHLORIDE	(6)	1	–	–	32 S	–	–	–	10 S	–	–	–	44 S	–
		2	–	–	40 S	–	–	–	16 S	–	–	–	55 S	–
		3	–	–	80 S	–	–	–	10 S	–	–	–	10 S	–
		6	50 Z	–	–	6 Z	10 Z	–	–	29 CZ	10 Z	–	–	–
1,1-DICHLOROETHANE	(9)	1	–	–	4	–	–	–	D(<1)	–	–	–	D(<1)	–
		2	–	–	7.6	–	–	–	D(<1)	–	–	–	D(<1)	–
		3	–	–	4	–	–	–	D(<1)	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	ND(<10)	–	–	ND(<1)C	ND(<10)	–	–	–
CHLOROFORM	(11)	1	–	–	.7	–	–	–	1.2	–	–	–	D(<1)	–
		2	–	–	1.5	–	–	–	1.5	–	–	–	D(<1)	–
		3	–	–	1.6	–	–	–	1	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	ND(<10)	–	–	ND(<1)C	ND(<10)	–	–	–
1,2-DICHLOROETHANE	(12)	1	–	–	3	–	–	–	D(<1)	–	–	–	D(<1)	–
		2	–	–	3.5	–	–	–	D(<1)	–	–	–	D(<1)	–
		3	–	–	3	–	–	–	D(<1)	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	ND(<10)	–	–	ND(<1)C	ND(<10)	–	–	–
1,1,1-TRICHLOROETHANE	(13)	1	–	–	1	–	–	–	1	–	–	–	D(<1)	–
		2	–	–	3.2	–	–	–	D(<1)	–	–	–	D(<1)	–
		3	–	–	4	–	–	–	D(<1)	–	–	–	D(<1)	–
		6	D(<10)A	–	–	ND(<1)	ND(<10)	–	–	15 C	ND(<10)	–	–	–
CARBON TETRACHLORIDE	(14)	1	–	–	.5	–	–	–	D(<1)	–	–	–	D(<1)	–
		2	–	–	2	–	–	–	D(<1)	–	–	–	D(<1)	–
		3	–	–	.5	–	–	–	D(<1)	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	ND(<10)	–	–	2 CZ	ND(<10)	–	–	–
BROMODICHLOROMETHANE	(15)	1	–	–	3 A	–	–	–	D(<1)	–	–	–	D(<1)	–
		2	–	–	15 A	–	–	–	D(<1)	–	–	–	D(<1)	–
		3	–	–	4 A	–	–	–	D(<1)	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	D(<10)A	–	–	ND(<1)C	ND(<10)	–	–	–
1,2-DICHLOROPROPANE	(16)	1	–	–	D(<1)	–	–	–	D(<1)	–	–	–	D(<1)	–
		2	–	–	1	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		3	–	–	ND(<1)	–	–	–	40	–	–	–	5	–
		6	ND(<10)	–	–	ND(<1)	D(<10)A	–	–	ND(<1)C	ND(<10)	–	–	–
TRICHLOROETHYLENE	(18)	1	–	–	ND(<1)	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		3	–	–	ND(<1)	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		6	20	–	–	ND(<1)	ND(<10)	–	–	ND(<1)C	ND(<10)	–	–	–
BENZENE	(22)	1	–	–	D(<10)	–	–	–	450	–	–	–	D(<1)	–
		2	–	–	40	–	–	–	550	–	–	–	D(<1)	–
		3	–	–	D(<10)E	–	–	–	480	–	–	–	D(<1)	–
		6	ND(<10)	–	–	–	G(100)	–	–	240 C	ND(<10)	–	–	–
1,1,2,2-TETRACHLOROETHENE	(24)	1	–	–	ND(<1)	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		2	–	–	ND(<1)	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		3	–	–	ND(<1)	–	–	–	ND(<1)	–	–	–	ND(<1)	–
		6	50	–	–	ND(<1)	ND(<10)	–	–	ND(<1)C	ND(<10)	–	–	–
TOLUENE	(26)	1	–	–	D(<1)	–	–	–	530	–	–	–	D(<1)	–
		2	–	–	D(<1)	–	–	–	750	–	–	–	D(<1)	–
		3	–	–	D(<1)	–	–	–	640	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	G(100)	–	–	80 C	ND(<10)	–	–	–
ETHYLBENZENE	(28)	1	–	–	D(<1)	–	–	–	40	–	–	–	D(<1)	–
		2	–	–	D(<1)	–	–	–	40	–	–	–	D(<1)	–
		3	–	–	D(<1)	–	–	–	50	–	–	–	D(<1)	–
		6	ND(<10)	–	–	ND(<1)	G(100)	–	–	ND(<1)C	ND(<10)	–	–	–

D(X) – COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) – COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)– COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
A – POSSIBLE IDENTIFICATION
C – ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
E – MAXIMUM VALUE, REPORTED VALUE MAY INCLUDE OTHER SPECIES WHICH CONTRIBUTE TO THE MEASURED CONCENTRATION
S – VALUE CONSIDERED ATYPICAL BY REPORTING LABORATORY
Z – BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION
7 – PURGE AND TRAP QC METHOD UTILIZING FID AND HALL DETECTORS.

TABLE A-25 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 5, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA MRI	RADIAN	COMPANY (8)	OTHER SPECTRIX	EPA MRI	RADIAN	COMPANY (8)	OTHER SPECTRIX	EPA MRI	RADIAN	COMPANY (8)	OTHER SPECTRIX
1,4-DICHLOROBENZENE	(2)	6	D(<.5)	-	-	ND(<1)	ND(<1)	-	-	ND(<1)	ND(<1)	-	-	ND(<1)
1,2-DICHLOROBENZENE	(4)	6	D(<.5)	-	-	ND(<1)	ND(<1)	-	-	ND(<1)	ND(<1)	-	-	ND(<1)
NAPHTHALENE	(8)	1	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	ND(<1)	-	-	-	106	-	-	ND(<1)	ND(<1)	-	-	ND(<1)
ACENAPHTHENE	(15)	1	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	1.8	-	-	ND(<1)	149	-	-	ND(<1)	ND(<1)	-	-	ND(<1)
FLUORENE	(17)	1	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	ND(<1)	-	-	ND(<1)	106	-	-	ND(<1)	ND(<1)	-	-	ND(<1)
PHENANTHRENE/ANTHRACENE	(24)	6	ND(<1)H	-	-	ND(<1)H	48 H	-	-	ND(<1)H	ND(<1)H	-	-	ND(<1)H
PHENANTHRENE	(25)	1	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-
		3	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-
ANTHRACENE	(26)	1	-	-	ND(<2)	-	-	-	ND(<2)	-	-	-	ND(<2)	-
		3	-	-	ND(<2)	-	-	-	ND(<2)	-	-	-	ND(<2)	-
FLUORANTHENE	(29)	1	-	-	ND(<.5)	-	-	-	8 E	-	-	-	ND(<.5)	-
		3	-	-	ND(<.5)	-	-	-	5 E	-	-	-	ND(<.5)	-
		6	D(<.2)	-	-	ND(<1)	ND(<1)	-	-	ND(<1)	ND(<1)	-	-	ND(<1)
PYRENE	(30)	1	-	-	ND(<.5)	-	-	-	3 E	-	-	-	ND(<.5)	-
		3	-	-	ND(<.5)	-	-	-	3 E	-	-	-	ND(<.5)	-
		6	D(<.1)	-	-	ND(<1)	5.1	-	-	-	D(<.5)	-	-	-
DI-N-BUTYL PHTHALATE	(31)	6	.4	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	ND(<1)
CHRYSENE	(36)	6	ND(<1)	-	-	-	.3	-	-	-	D(<.1)	-	-	-
PHENOL	(53)	1	-	-	ND(<20)	-	-	-	3000	-	-	-	ND(<20)	-
		2	-	-	ND(<20)	-	-	-	6000	-	-	-	ND(<20)	-
		3	-	-	ND(<20)	-	-	-	8000	-	-	-	ND(<20)	-
		6	ND(<50)	-	-	ND(<1)	Q(100)	-	-	-	ND(<50)	-	-	-
2-4-DIMETHYLPHENOL	(55)	6	ND(<50)	-	-	ND(<1)	Q(100)	-	-	ND(<1)	ND(<50)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
E - MAXIMUM VALUE, REPORTED VALUE MAY INCLUDE OTHER SPECIES WHICH CONTRIBUTE TO THE MEASURED CONCENTRATION
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.
8 - PHENOLS AND POLYNUCLEAR AROMATIC HYDROCARBONS ANALYZED BY HPLC METHODS.

TABLE A-26 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 5, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER EPA RSKERL(3)	INTAKE WATER RADIAN	INTAKE WATER COMPANY	INTAKE WATER OTHER	WASTEWATER FEED TO BIOTREATMENT EPA RSKERL(3)	WASTEWATER FEED TO BIOTREATMENT RADIAN	WASTEWATER FEED TO BIOTREATMENT COMPANY	WASTEWATER FEED TO BIOTREATMENT OTHER	FINAL EFFLUENT EPA RSKERL(3)	FINAL EFFLUENT RADIAN	FINAL EFFLUENT COMPANY	FINAL EFFLUENT OTHER
ZINC	(1)	1	-	-	106	-	-	-	60	-	-	-	46	-
		2	-	-	106	-	-	-	41	-	-	-	55	-
		3	-	-	28	-	-	-	55	-	-	-	46	-
		6	110	-	-	-	50	-	-	-	30	-	-	-
CHROMIUM	(2)	1	-	-	37	-	-	-	106	-	-	-	63	-
		2	-	-	66	-	-	-	79	-	-	-	71	-
		3	-	-	49	-	-	-	89	-	-	-	60	-
		6	35	-	-	-	76	-	-	-	36	-	-	-
COPPER	(3)	1	-	-	47	-	-	-	ND(<5)	-	-	-	48	-
		2	-	-	ND(<5)	-	-	-	5	-	-	-	10	-
		3	-	-	36	-	-	-	26	-	-	-	14	-
		6	8	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
LEAD	(4)	1	-	-	30	-	-	-	37	-	-	-	28	-
		2	-	-	17	-	-	-	26	-	-	-	30	-
		3	-	-	19	-	-	-	20	-	-	-	18	-
		6	23	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5)	1	-	-	1.1	-	-	-	1	-	-	-	2	-
		2	-	-	.8	-	-	-	.8	-	-	-	1.2	-
		3	-	-	.9	-	-	-	1.9	-	-	-	2.1	-
		6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6)	1	-	-	25	-	-	-	27	-	-	-	56	-
		2	-	-	21	-	-	-	27	-	-	-	32	-
		3	-	-	30	-	-	-	64	-	-	-	67	-
		6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7)	1	-	-	ND(<5)	-	-	-	8	-	-	-	6	-
		2	-	-	ND(<5)	-	-	-	6	-	-	-	8	-
		3	-	-	ND(<5)	-	-	-	7	-	-	-	ND(<5)	-
		6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8)	1	-	-	58	-	-	-	44	-	-	-	82	-
		2	-	-	53	-	-	-	67	-	-	-	69	-
		3	-	-	70	-	-	-	80	-	-	-	66	-
		6	51	-	-	-	28	-	-	-	19	-	-	-
ARSENIC	(9)	1	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-
		2	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-
		3	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-
		6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
SELENIUM	(10)	1	-	-	7	-	-	-	17	-	-	-	19	-
		2	-	-	12	-	-	-	22	-	-	-	12	-
		3	-	-	3	-	-	-	32	-	-	-	30	-
		6	ND(<10)	-	-	-	ND(<10)	-	-	-	12	-	-	-
SILVER	(11)	1	-	-	6	-	-	-	ND(<5)	-	-	-	174	-
		2	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-
		3	-	-	ND(<5)	-	-	-	160	-	-	-	ND(<5)	-
		6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12)	1	-	-	2	-	-	-	13	-	-	-	3	-
		2	-	-	4	-	-	-	9	-	-	-	16	-
		3	-	-	3	-	-	-	10	-	-	-	2	-
		6	2	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
		2	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-
		3	ND(<.5)	-	13	-	ND(<.5)	-	.09	-	ND(<.5)	-	.07	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-27 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 6, UG/L

PARAMETER		SAMPLE DATE	MAKEUP WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA MRI	RADIAN	COMPANY (7,9)	OTHER	EPA MRI	RADIAN	COMPANY (7,9)	OTHER	EPA MRI	RADIAN	COMPANY (7,9)	OTHER
METHYLENE CHLORIDE	(6)	1	-	-	6	-	-	-	-	-	-	-	-	-
		2	-	-	5	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	5	-	-	-	-	-	-	-	-	-
		6	D(<10)Z	-	-	-	70 Z	-	-	-	D(<10)Z	-	-	-
1,1,1-TRICHLOROETHANE	(13)	1	-	-	55	-	-	-	-	-	-	-	-	-
		2	-	-	58	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	51	-	-	-	-	-	-	-	-	-
		6	9(50)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
CARBON TETRACHLORIDE	(14)	2	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	9(50)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
BENZENE	(22)	1	-	-	4	-	-	-	-	-	-	-	-	-
		2	-	-	8	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
TOLUENE	(26)	1	-	-	13	-	-	-	-	-	-	-	-	-
		2	-	-	15	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
ETHYLBENZENE	(28)	1	-	-	D(<.5)	-	-	-	-	-	-	-	-	-
		2	-	-	D(<.5)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	.6	-	-	-	-	-	-	-	-	-
		6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION
7 - PURGE AND TRAP QC METHOD UTILIZING FID AND HALL DETECTORS.
9 - EPA AND COMPANY SAMPLES WERE COLLECTED AND ANALYZED. DATA IS FROM COMPANY SAMPLES.

TABLE A-28 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 6, UG/L

PARAMETER	SAMPLE DATE	MAKEUP WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER	EPA MRI	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<1)	-	3.6	-	ND(<1)	-	ND(<10)	-	ND(<1)	-	.1	-
ACENAPHTHENE	(15) 6	ND(<1)	-	5	-	ND(<1)	-	ND(<10)	-	ND(<1)	-	ND(<10)	-
PHENANTHRENE/ANTHRACENE	(24) 6	164 H	-	146 HC	-	1.8 H	-	4.4 HC	-	ND(<1)H	-	.4 HC	-
FLUORANTHENE	(29) 6	29	-	3.4 C	-	ND(<1)	-	ND(<10)C	-	ND(<1)	-	.2 C	-
PYRENE	(30) 6	143	-	65 C	-	10	-	2.9 C	-	ND(<1)	-	.5 C	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	49	-	76 CH	-	6.5	-	16 CH	-	.8	-	1.4 CH	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	ND(<1)	-	5 E	-	ND(<1)	-	2.2 E	-	ND(<1)	-	10 E	-
BENZO(B)/(K)FLUORANTHENE	(39) 6	ND(<1)	-	3.2 HC	-	ND(<1)	-	.9 HC	-	ND(<1)	-	.2 HC	-
BENZO(A)PYRENE	(42) 6	33	-	8 CE	-	9.5	-	7.8 CE	-	1.3	-	.9 CE	-
INDENO(1,2,3-C,D)PYRENE	(43) 6	ND(<1)	-	.4 C	-	ND(<1)	-	.5 C	-	ND(<1)	-	ND(<10)C	-
BENZO(G,H,I)PERYLENE	(45) 6	ND(<1)	-	2.5 C	-	ND(<1)	-	1.2 C	-	ND(<1)	-	ND(<10)C	-
PHENOL	(53) 6	ND(<50)	-	4	-	ND(<50)	-	6	-	ND(<50)	-	59	-
2-4-DIMETHYLPHENOL	(55) 6	ND(<50)	-	5 E	-	ND(<50)	-	11 E	-	ND(<50)	-	8 E	-
P-CHLORO-M-CRESOL	(58) 6	ND(<50)	-	ND(<15)	-	ND(<50)	-	ND(<15)	-	ND(<50)	-	.2	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
E - MAXIMUM VALUE. REPORTED VALUE MAY INCLUDE OTHER SPECIES WHICH CONTRIBUTE TO THE MEASURED CONCENTRATION
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-29 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 6, UG/L

PARAMETER		SAMPLE DATE	MAKEUP WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER	EPA RSKERL(3)	RADIAN	COMPANY	OTHER
ZINC	(1)	1	-	-	230	-	-	-	220	-	-	-	170	-
		2	-	-	220	-	-	-	320	-	-	-	170	-
		3	-	-	200	-	-	-	360	-	-	-	190	-
		6	120	-	-	-	330	-	-	-	100	-	-	-
CHROMIUM	(2)	1	-	-	53	-	-	-	23	-	-	-	14	-
		2	-	-	67	-	-	-	33	-	-	-	11	-
		3	-	-	58	-	-	-	58	-	-	-	20	-
		6	60	-	-	-	41	-	-	-	7	-	-	-
COPPER	(3)	1	-	-	42	-	-	-	320	-	-	-	78	-
		2	-	-	270	-	-	-	350	-	-	-	96	-
		3	-	-	290	-	-	-	460	-	-	-	120	-
		6	210	-	-	-	500	-	-	-	125	-	-	-
LEAD	(4)	1	-	-	3	-	-	-	5	-	-	-	ND(<)I	-
		2	-	-	3	-	-	-	6	-	-	-	ND(<)I	-
		3	-	-	3	-	-	-	5	-	-	-	2	-
		6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5)	1	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		2	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		3	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6)	1	-	-	6	-	-	-	11	-	-	-	11	-
		2	-	-	6	-	-	-	6	-	-	-	8	-
		3	-	-	6	-	-	-	6	-	-	-	9	-
		6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7)	1	-	-	ND(<)I	-	-	-	2	-	-	-	ND(<)I	-
		2	-	-	ND(<)I	-	-	-	2	-	-	-	ND(<)I	-
		3	-	-	ND(<)I	-	-	-	ND(<)1	-	-	-	ND(<)I	-
		6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8)	1	-	-	33	-	-	-	115	-	-	-	48	-
		2	-	-	50	-	-	-	65	-	-	-	60	-
		3	-	-	35	-	-	-	115	-	-	-	65	-
		6	58	-	-	-	77	-	-	-	58	-	-	-
ARSENIC	(9)	1	-	-	18	-	-	-	27	-	-	-	20	-
		2	-	-	10	-	-	-	22	-	-	-	15	-
		3	-	-	18	-	-	-	22	-	-	-	14	-
		6	27	-	-	-	41	-	-	-	31	-	-	-
SELENIUM	(10)	1	-	-	19	-	-	-	21	-	-	-	11	-
		2	-	-	19	-	-	-	26	-	-	-	9	-
		3	-	-	19	-	-	-	35	-	-	-	14	-
		6	12	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
SILVER	(11)	1	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		2	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		3	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12)	1	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		2	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		3	-	-	ND(<)I	-	-	-	ND(<)I	-	-	-	ND(<)I	-
		6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	ND(<.5)	-	ND(<)I	-	ND(<.5)	-	ND(<)I	-	ND(<.5)	-	ND(<)I	-
		2	ND(<.5)	-	ND(<)I	-	ND(<.5)	-	ND(<)I	-	ND(<.5)	-	ND(<)I	-
		3	ND(<.5)	-	ND(<)I	-	ND(<.5)	-	ND(<)I	-	ND(<.5)	-	ND(<)I	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
I - CONCENTRATION REPORTED AS 0.0
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-30 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 7, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA	RADIAN	COMPANY	OTHER	EPA	RADIAN	COMPANY	OTHER	EPA	RADIAN	COMPANY	OTHER
METHYLENE CHLORIDE	(6)	1	-	6 Z	-	-	-	20 Z	-	-	-	ND(<.2)Z	ND(<1)	-
		2	-	9 Z	-	-	-	23 Z	-	-	-	4 Z	ND(<1)	-
		3	-	10 Z	-	-	-	49 Z	-	-	-	4 Z	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
TRANS-1,2-DICHLOROETHYLENE	(10)	1	-	1	-	-	-	ND(<.7)	-	-	-	ND(<.7)	ND(<1)	-
		2	-	4	-	-	-	1	-	-	-	ND(<.7)	ND(<1)	-
		3	-	3	-	-	-	ND(<.7)	-	-	-	ND(<.7)	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
CHLOROFORM	(11)	1	-	29	-	-	-	2	-	-	-	16	ND(<1)	-
		2	-	31	-	-	-	7	-	-	-	14	ND(<1)	-
		3	-	37	-	-	-	3	-	-	-	10	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
1,1,1-TRICHLOROETHANE	(13)	1	-	2	-	-	-	ND(<.3)	-	-	-	ND(<.3)	ND(<1)	-
		2	-	2	-	-	-	ND(<.3)	-	-	-	ND(<.3)	ND(<1)	-
		3	-	ND(<.3)	-	-	-	ND(<.3)	-	-	-	ND(<.3)	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
TRANS-1,3-DICHLOROPROPENE	(17)	1	-	ND(<.7)	-	-	-	ND(<.7)	-	-	-	ND(<.7)	ND(<1)	-
		2	-	ND(<.7)	-	-	-	2	-	-	-	ND(<.7)	ND(<1)	-
		3	-	ND(<.7)	-	-	-	ND(<.7)	-	-	-	ND(<.7)	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
TRICHLOROETHYLENE	(18)	1	-	1	-	-	-	2	-	-	-	D(<1)	ND(<1)	-
		2	-	D(<1)	-	-	-	4	-	-	-	1	ND(<1)	-
		3	-	1	-	-	-	5	-	-	-	D(<1)	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
BENZENE	(22)	1	-	D(<1)	-	-	-	4700	-	-	-	D(<1)	ND(<1)Z	-
		2	-	D(<1)	-	-	-	1800	-	-	-	D(<1)	ND(<1)Z	-
		3	-	D(<1)	-	-	-	3300	-	-	-	ND(<.5)	ND(<1)Z	-
		6	-	-	ND(<1)	-	-	-	8400	-	-	-	-	-
BROMOFORM	(23)	1	-	ND(<.3)	-	-	-	ND(<.3)	-	-	-	ND(<.3)	ND(<1)	-
		2	-	ND(<.3)	-	-	-	D(<1)	-	-	-	ND(<.3)	ND(<1)	-
		3	-	ND(<.3)	-	-	-	D(<1)	-	-	-	ND(<.3)	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
1,1,2,2-TETRACHLOROETHENE	(24)	1	-	ND(<.4)	-	-	-	6	-	-	-	ND(<.4)	ND(<1)	-
		2	-	ND(<.4)	-	-	-	3	-	-	-	ND(<.4)	ND(<1)	-
		3	-	ND(<.4)	-	-	-	6	-	-	-	ND(<.4)	ND(<1)	-
		6	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-
TOLUENE	(26)	1	-	3	-	-	-	4200	-	-	-	D(<1)	ND(<1)Z	-
		2	-	D(<1)	-	-	-	820	-	-	-	D(<1)	ND(<1)Z	-
		3	-	D(<1)	-	-	-	2900	-	-	-	D(<1)	ND(<1)Z	-
		6	-	-	ND(<1)	-	-	-	8500	-	-	-	-	-
ETHYLBENZENE	(28)	1	-	D(<1)	-	-	-	440	-	-	-	D(<1)	ND(<1)Z	-
		2	-	D(<1)	-	-	-	250	-	-	-	D(<1)	ND(<1)Z	-
		3	-	D(<1)	-	-	-	460	-	-	-	D(<1)	ND(<1)Z	-
		6	-	-	ND(<1)	-	-	-	200 C	-	-	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION

TABLE A-31 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 7, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA	RADIAN	COMPANY	OTHER EXXON(5)	EPA	RADIAN	COMPANY	OTHER EXXON(5)	EPA	RADIAN	COMPANY	OTHER EXXON(5)
NAPHTHALENE	(8) 6	-	ND(<.1)	ND(<1)Z	-	-	1100	5200 CZ	-	-	ND(<.1)	ND(<1)Z	-
FLUORENE	(17) 6	-	ND(<.1)	ND(<1)	-	-	62	ND(<1)	5 C	-	ND(<.1)	ND(<1)	ND(<.3)
PHENANTHRENE/ANTHRACENE	(24) 6	-	ND(<.1)H	ND(<1)	-	-	99 H	ND(<1)	-	-	ND(<.1)	ND(<1)	-
PHENANTHRENE	(25) 6	-	-	-	-	-	-	-	32 C	-	-	-	ND(<.2)
ANTHRACENE	(26) 6	-	-	-	-	-	-	-	ND(<.03)C	-	-	-	ND(<.01)
DIETHYL PHTHALATE	(28) 6	-	4	ND(<1)	-	-	5.5	ND(<1)	-	-	5	ND(<1)	-
FLUORANTHENE	(29) 6	-	ND(<.1)	ND(<1)	ND(<.03)	-	23	ND(<1)	2 C	-	ND(<.1)	ND(<1)	ND(<.05)
PYRENE	(30) 6	-	ND(<.1)	ND(<1)	ND(<.02)	-	6.9	ND(<1)	6.4 C	-	.3	ND(<1)	.3
DI-N-BUTYL PHTHALATE	(31) 6	-	1	ND(<1)	-	-	D(<1)	ND(<1)	-	-	32	ND(<1)	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	-	ND(<.1)H	ND(<1)	-	-	13 H	ND(<1)	-	-	.1 H	ND(<1)	
CHRYSENE	(36) 6	-	-	-	ND(<.01)	-	-	- C	2.6	-	-	-	ND(<.02)
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	-	2	ND(<1)	-	-	2.9	ND(<1)	-	-	15	ND(<1)	-
BENZ(A)ANTHRACENE	(38) 6	-	-	-	ND(<.01)	-	-	-	1.4 C	-	-	-	.01
BENZO(A)PYRENE	(42) 6	-	ND(<.1)	ND(<1)	.03	-	4.4	ND(<1)	1.1 C	-	.4	ND(<1)	.03
DIBENZO(A,H)ANTHRACENE	(44) 6	-	ND(<.3)	ND(<1)	-	-	ND(<.3)	ND(<1)	.4 C	-	ND(<.3)	ND(<1)	ND(<.03)
BENZO(G,H,I)PERYLENE	(45) 6	-	ND(<.2)	ND(<1)	ND(<.1)	-	ND(<.2)	ND(<1)	.6 C	-	ND(<.2)	ND(<1)	ND(<.2)
PHENOL	(53) 6	-	D(<1)	ND(<1)Z	-	-	15000	26000Z	-	-	ND(<.1)	ND(<1)Z	-
2-4-DIMETHYLPHENOL	(55) 6	-	ND(<.2)	ND(<1)	-	-	1500	1200	-	-	ND(<.2)	ND(<1)	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION
5 - GC-UV METHOD.

TABLE A-32 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 7, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER
ZINC	(1) 6	61	120	120	-	55	78	70	-	43	82	67 C	-
CHROMIUM	(2) 6	40	11	ND(<1)	-	72	800	690	-	40	46	28	-
COPPER	(3) 6	ND(<5)	68	ND(<1)	-	ND(<5)	26	7	-	ND(<5)	16	12	-
LEAD	(4) 6	ND(<15)	1.2	ND(<1)	-	ND(<15)	4	ND(<1)	-	ND(<15)	5.3	7	-
BERYLLIUM	(5) 6	ND(<3)	ND(<.1)	ND(<1)	-	ND(<3)	2.2	1	-	ND(<3)	.7	1	-
ANTIMONY	(6) 6	ND(<25)	.4	ND(<1)	-	360	68	240	-	370	68	190	-
THALLIUM	(7) 6	ND(<15)	ND(<.1)	ND(<1)	-	ND(<15)	33	1	-	ND(<15)	9.5	ND(<1)	-
NICKEL	(8) 6	ND(<15)	1	ND(<1)	-	ND(<15)	3.6	27	-	ND(<15)	3.6	18	-
ARSENIC	(9) 6	ND(<20)	18	ND(<1)	-	ND(<20)	23	6	-	ND(<20)	16	2	-
SELENIUM	(10) 6	ND(<20)	15	ND(<1)	-	ND(<20)	15	8	-	ND(<20)	15	ND(<1)	-
SILVER	(11) 6	ND(<5)	1.2	ND(<1)	-	ND(<5)	2.3	ND(<1)	-	ND(<5)	.8	ND(<1)	-
CADMIUM	(12) 6	ND(<1)	.2	ND(<1)	-	ND(<1)	.6	ND(<1)	-	ND(<1)	.8	ND(<1)	-
MERCURY	(13) 6	ND(<.5)	.3	ND(<1)	-	ND(<.5)	.8	ND(<1)	-	ND(<.5)	.4	ND(<1)	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE

TABLE A-33 CONCENTRATION OF TRACE ELEMENTS AT REFINERY B, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER
ZINC	(1)	2	-	-	80	-	-	-	120	-	-	-	40	-
		3	-	-	10	-	-	-	140	-	-	-	10	-
		6	ND(<10)	-	-	-	74	-	-	-	ND(<10)	-	-	-
CHROMIUM	(2)	2	-	-	ND(<10)	-	-	-	330	-	-	-	130	-
		3	-	-	ND(<10)	-	-	-	350	-	-	-	130	-
		6	8	-	-	-	240	-	-	-	110	-	-	-
COPPER	(3)	2	-	-	20	-	-	-	50	-	-	-	10	-
		3	-	-	20	-	-	-	40	-	-	-	ND(<10)	-
		6	ND(<5)	-	-	-	30	-	-	-	ND(<5)	-	-	-
LEAD	(4)	2	-	-	10	-	-	-	40	-	-	-	20	-
		3	-	-	ND(<10)	-	-	-	20	-	-	-	ND(<10)	-
		6	ND(<15)	-	-	-	27	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5)	6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6)	6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8)	2	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		3	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
ARSENIC	(9)	2	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		3	-	-	ND(<10)	-	-	-	10	-	-	-	ND(<10)	-
		6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SELENIUM	(10)	2	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		3	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SILVER	(11)	2	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-
		3	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-
		6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12)	2	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		3	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-
		6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	2	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		3	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-34 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 9, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA	RADIAN	COMPANY (2)	OTHER	EPA	RADIAN	COMPANY (2)	OTHER	EPA	RADIAN	COMPANY (2)	OTHER
METHYLENE CHLORIDE	(6)	1	-	-	D(<.5)	-	-	-	D(<.5)	-	-	-	D(<.5)	-
		2	-	-	.6 C	-	-	-	-	-	-	-	D(<.5)	-
		3	-	-	-	-	-	-	D(<.5) C	-	-	-	D(<.5)	-
		6	-	19 Z	-	-	-	9 Z	-	-	-	12 Z	-	-
CHLOROFORM	(11)	1	-	-	ND(<1)	-	-	-	9	-	-	-	D(<.5)	-
		2	-	-	D(<.5)C	-	-	-	-	-	-	-	D(<.5)	-
		3	-	-	-	-	-	-	ND(<1) C	-	-	-	D(<.5)	-
		6	-	ND(<.3)	-	-	-	ND(<.3)	-	-	-	ND(<.3)	-	-
1,2-DICHLOROETHANE	(12)	1	-	-	-	-	-	-	D(<.5) E	-	-	-	D(<.5)E	-
		2	-	-	D(<.5)E	-	-	-	-	-	-	-	ND(<1)E	-
		3	-	-	-	-	-	-	ND(<1) CE	-	-	-	ND(<1)E	-
		6	-	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-
TRANS-1,3-DICHLOROPROPENE	(17)	1	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		2	-	-	ND(<1)	-	-	-	-	-	-	-	ND(<1)	-
		3	-	-	-	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	-	ND(<.7)	-	-	-	3	-	-	-	1	-	-
TRICHLOROETHYLENE	(18)	1	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		2	-	-	ND(<1)	-	-	-	-	-	-	-	ND(<1)	-
		3	-	-	-	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	-	D(<1)	-	-	-	2	-	-	-	2	-	-
CIS-1,3-DICHLOROPROPENE	(20)	1	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		2	-	-	ND(<1)	-	-	-	-	-	-	-	ND(<1)	-
		3	-	-	-	-	-	-	ND(<1)	-	-	-	ND(<1)	-
		6	-	ND(<.7)	-	-	-	20	-	-	-	ND(<.7)	-	-
BENZENE	(22)	6	-	D(<1)Z	D(<2)	-	-	53	1000	-	-	D(<1)Z	D(<10)	-
TOLUENE	(26)	6	-	1 Z	D(<2)	-	-	55	2000	-	-	D(<1)Z	D(<10)	-
ETHYLBENZENE	(28)	6	-	D(<1)Z	D(<20)	-	-	5	100	-	-	D(<1)Z	D(<40)	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
E - MAXIMUM VALUE, REPORTED VALUE MAY INCLUDE OTHER SPECIES WHICH CONTRIBUTE TO THE MEASURED CONCENTRATION
Z - BLANK DATA FOR THIS PARAMETER INDICATES CONTAMINATION
2 - ORGANOHALIDES BY BELLAR GC METHOD; OTHER VOLATILE SPECIES BY GROB GC METHOD.

TABLE A-35 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 9, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA	RADIAN	COMPANY (6)	OTHER	EPA	RADIAN	COMPANY (6)	OTHER	EPA	RADIAN	COMPANY (6)	OTHER
NAPHTHALENE	(8) 6	-	ND(<.1)	D(<5)	-	-	22	300	-	-	ND(<.1)	50	-
ACENAPHTHYLENE	(14) 6	-	ND(<.1)	D(<40)	-	-	ND(<.1)	200	-	-	ND(<.1)	D(<10)	-
ACENAPHTHENE	(15) 6	-	ND(<.1)	D(<40)	-	-	ND(<.1)	30	-	-	ND(<.1)	D(<10)	-
FLUORENE	(17) 6	-	ND(<.1)	ND(<.1)	-	-	2.9	ND(<.1)C	-	-	.6	ND(<.3)C	-
PHENANTHRENE/ANTHRACENE	(24) 6	-	ND(<.1)H	-	-	-	6.4 H	-	-	-	ND(<.1)H	-	-
PHENANTHRENE	(25) 6	-	-	ND(<.08)	-	-	-	2.7 C	-	-	-	ND(<.2)C	-
ANTHRACENE	(26) 6	-	-	ND(<.01)	-	-	-	ND(<.01)C	-	-	-	ND(<.01)C	-
DIETHYL PHTHALATE	(28) 6	-	5.5	-	-	-	60	-	-	-	ND(<.3)	-	-
FLUORANTHENE	(29) 6	-	ND(<.1)	ND(<.02)	-	-	ND(<.1)	.3 C	-	-	ND(<.1)	.1 C	-
PYRENE	(30) 6	-	ND(<.1)	ND(<.02)	-	-	1	1 C	-	-	1.9	1.1 C	-
DI-N-BUTYL PHTHALATE	(31) 6	-	1.4	-	-	-	2.8	-	-	-	2	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	-	ND(<.1)H	-	-	-	.3 H	-	-	-	.5 H	-	-
CHRYSENE	(36) 6	-	-	ND(<.01)	-	-	-	.3	-	-	-	.2 C	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	-	16	-	-	-	1.8	-	-	-	2.6	-	-
BENZ(A)ANTHRACENE	(38) 6	-	-	ND(<.01)	-	-	-	.1 C	-	-	-	.08 C	-
BENZO(A)PYRENE	(42) 6	-	ND(<.1)	.04	-	-	ND(<.1)	.1 C	-	-	.4	.1 C	-
BENZO(G,H,I)PERYLENE	(45) 6	-	ND(<.2)	ND(<.07)	-	-	ND(<.2)	.2 C	-	-	ND(<.2)	.2 C	-
PHENOL	(53) 6	-	ND(<.1)	-	-	-	13000	-	-	-	1.9	-	-
2-4-DIMETHYLPHENOL	(55) 6	-	ND(<.2)	-	-	-	3000	-	-	-	5.5	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
C - ONE OF TWO OR MORE REPORTED VALUES FOR THIS SAMPLE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL
6 - NAPHTHALENE, ACENAPHTHALENE, AND ACENAPHTHENE BY GROB GC METHOD; OTHER SPECIES BY GC-UV METHOD.

TABLE A-36 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 9, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RSKERL	RADIAN	COMPANY	OTHER HAWKSLEY	EPA RSKERL	RADIAN	COMPANY	OTHER HAWKSLEY	EPA RSKERL	RADIAN	COMPANY	OTHER HAWKSLEY
ZINC	(1)	6	15	23	10	-	30	48	12	-	25	27	10	-
CHROMIUM	(2)	1	-	-	-	10	-	-	-	25	-	-	-	71
		2	-	-	-	32	-	-	-	75	-	-	-	65
		3	-	-	-	5	-	-	-	32	-	-	-	-
		6	ND(<5)	5.8	ND(<10)	-	ND(<5)	79	50	-	ND(<5)	94	50	-
COPPER	(3)	6	ND(<5)	65	26	-	7	62	6	-	ND(<5)	52	3	-
LEAD	(4)	6	ND(<15)	11	9	-	ND(<15)	8	26	-	ND(<15)	3	46	-
BERYLLIUM	(5)	6	ND(<3)	ND(<1)	ND(<10)	-	ND(<3)	ND(<1)	ND(<10)	-	ND(<3)	ND(<1)	ND(<10)	-
ANTIMONY	(6)	6	ND(<25)	14	ND(<30)	-	ND(<25)	37	ND(<30)	-	ND(<25)	36	ND(<30)	-
THALLIUM	(7)	6	ND(<15)	ND(<2)	-	-	ND(<15)	ND(<2)	-	-	ND(<15)	ND(<2)	-	-
NICKEL	(8)	6	ND(<15)	3.5	ND(<2)	-	ND(<15)	4.9	ND(<2)	-	ND(<15)	2.1	ND(<2)	-
ARSENIC	(9)	6	ND(<20)	ND(<1)	-	-	ND(<20)	10	-	-	ND(<20)	14	-	-
SELENIUM	(10)	6	ND(<20)	4	-	-	ND(<20)	9	-	-	ND(<20)	74	-	-
SILVER	(11)	6	ND(<5)	9	1	-	ND(<5)	6.3	3	-	ND(<5)	4.2	2	-
CADMIUM	(12)	6	ND(<1)	.8	ND(<1)	-	ND(<1)	1.5	ND(<1)	-	ND(<1)	1.1	ND(<1)	-
MERCURY	(13)	6	ND(<.5)	.4	-	-	ND(<.5)	.5	-	-	ND(<.5)	.8	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-37 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 10, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER
ZINC	(1)	6	15	-	-	-	30	-	-	-	25	-	-	-
CHROMIUM	(2)	6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
COPPER	(3)	6	ND(<5)	-	-	-	7	-	-	-	ND(<5)	-	-	-
LEAD	(4)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5)	6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6)	6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8)	6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
ARSENIC	(9)	6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SELENIUM	(10)	6	ND(<20)	-	-	-	ND(<20)	-	-	-	20	-	-	-
SILVER	(11)	6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	6	ND(<.5)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-38 CONCENTRATION OF PRIORITY VOLATILE ORGANICS AT REFINERY 11, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA	RADIAN	COMPANY	OTHER	EPA	RADIAN	COMPANY	OTHER	EPA	RADIAN	COMPANY	OTHER
METHYLENE CHLORIDE	(6) 6	-	19	-	-	-	4.9	-	-	-	8	-	-
CHLOROFORM	(11) 6	-	1	-	-	-	ND(<.3)	-	-	-	ND(<.3)	-	-
1,1,1-TRICHLORGETHANE	(13) 6	-	1	-	-	-	1.8	-	-	-	ND(<.3)	-	-
TRICHLORDETHYLENE	(18) 6	-	1	-	-	-	D(<1)	-	-	-	D(<1)	-	-
BENZENE	(22) 6	-	D(<1)	-	-	-	31000	-	-	-	D(<1)	-	-
1,1,2,2-TETRACHLORDETHENE	(24) 6	-	1	-	-	-	ND(<.4)	-	-	-	ND(<.4)	-	-
TOLUENE	(26) 6	-	D(<1)	-	-	-	44000	-	-	-	D(<1)	-	-
ETHYLBENZENE	(28) 6	-	D(<1)	-	-	-	ND(<.5)	-	-	-	ND(<.5)	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
C(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-39 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 11, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA	RADIAN	COMPANY	OTHER	EPA	RADIAN	COMPANY	OTHER	EPA	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	-	ND(<.1)	-	-	-	240	-	-	-	ND(<.1)	-	-
FLUORENE	(17) 6	-	ND(<.1)	-	-	-	21	-	-	-	ND(<.1)	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	-	ND(<.1)H	-	-	-	69 H	-	-	-	ND(<.1)H	-	-
DIETHYL PHTHALATE	(28) 6	-	2.9	-	-	-	16	-	-	-	4.3	-	-
FLUORANTHENE	(29) 6	-	ND(<.1)	-	-	-	3.9	-	-	-	ND(<.1)	-	-
PYRENE	(30) 6	-	.2	-	-	-	5.4	-	-	-	ND(<.1)	-	-
DI-N-BUTYL PHTHALATE	(31) 6	-	2.2	-	-	-	ND(<.1)	-	-	-	D(<1)	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	-	ND(<.1)H	-	-	-	1.8 H	-	-	-	ND(<.1)H	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	-	D(<1)	-	-	-	ND(<.1)	-	-	-	ND(<.1)	-	-
PHENOL	(53) 6	-	ND(<.1)	-	-	-	30	-	-	-	ND(<.1)	-	-
2-4-DIMETHYLPHENOL	(55) 6	-	ND(<.2)	-	-	-	80	-	-	-	2.2	-	-
2.4-DICHLOROPHENOL	(57) 6	-	D(<1)	-	-	-	ND(<.1)	-	-	-	ND(<.1)	-	-
4,6-DINITRO-O-CRESOL	(62) 6	-	D(<1)	-	-	-	ND(<.6)	-	-	-	D(<1)	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
C(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-40 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 11, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER
ZINC	(1)	6	45	-	10	-	1400	-	1300	-	120	-	30	-
CHROMIUM	(2)	6	5	-	2	-	1600	-	1100	-	73	-	230	-
COPPER	(3)	6	6	-	ND(<20)	-	280	-	ND(<20)	-	18	-	ND(<20)	-
LEAD	(4)	6	ND(<15)	-	20	-	70	-	75	-	ND(<15)	-	10	-
BERYLLIUM	(5)	6	ND(<3)	-	ND(<1)	-	ND(<3)	-	ND(<1)	-	ND(<3)	-	ND(<1)	-
ANTIMONY	(6)	6	ND(<25)	-	ND(<50)	-	ND(<25)	-	ND(<50)	-	ND(<25)	-	ND(<50)	-
THALLIUM	(7)	6	ND(<15)	-	ND(<10)	-	ND(<15)	-	ND(<10)	-	ND(<15)	-	ND(<10)	-
NICKEL	(8)	6	ND(<15)	-	2	-	28	-	52	-	ND(<15)	-	9	-
ARSENIC	(9)	6	ND(<20)	-	22	-	ND(<20)	-	50	-	ND(<20)	-	70	-
SELENIUM	(10)	6	ND(<20)	-	ND(<10)	-	ND(<20)	-	ND(<10)	-	ND(<20)	-	ND(<10)	-
SILVER	(11)	6	ND(<5)	-	ND(<5)	-	ND(<5)	-	ND(<5)	-	ND(<5)	-	ND(<5)	-
CADMIUM	(12)	6	ND(<1)	-	ND(<1)	-	3	-	ND(<1)	-	1	-	ND(<1)	-
MERCURY	(13)	6	ND(<.5)	-	.3	-	ND(<.5)	-	.5	-	ND(<.5)	-	.3	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-41 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 12, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER	EPA RSKERL	RADIAN	COMPANY	OTHER
ZINC	(1) 6	75	-	-	-	140	-	-	-	90	-	-	-
CHROMIUM	(2) 6	ND(<5)	-	-	-	73	-	-	-	24	-	-	-
COPPER	(3) 6	180	-	-	-	6	-	-	-	8	-	-	-
LEAD	(4) 6	25	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
BERYLLIUM	(5) 6	ND(<3)	-	-	-	ND(<3)	-	-	-	ND(<3)	-	-	-
ANTIMONY	(6) 6	ND(<25)	-	-	-	ND(<25)	-	-	-	ND(<25)	-	-	-
THALLIUM	(7) 6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
NICKEL	(8) 6	ND(<15)	-	-	-	ND(<15)	-	-	-	ND(<15)	-	-	-
ARSENIC	(9) 6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SELENIUM	(10) 6	ND(<20)	-	-	-	ND(<20)	-	-	-	ND(<20)	-	-	-
SILVER	(11) 6	ND(<5)	-	-	-	ND(<5)	-	-	-	ND(<5)	-	-	-
CADMIUM	(12) 6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-

D(X). - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-42 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 13 UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (R2)			
		EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<10)	-	-	-	950	-	-	-	ND(<10)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	ND(<10)H	-	-	-	190 H	-	-	-	ND(<10)H	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	150	-	-	-	290	-	-	-	900	-	-	-
PHENOL	(53) 6	ND(<10)	-	-	-	2200	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL

TABLE A-42 (CONTINUED) CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 13, UG/L

PARAMETER	SAMPLE DATE	FINAL EFFLUENT			
		EPA RETA	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<10)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	ND(<10)H	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	310	-	-	-
PHENOL	(53) 6	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-43 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 13, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (R2)			
			EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
ZINC	(1)	1	-	-	-	-	630	-	-	-	930	-	-	-
		2	-	-	-	-	670	-	-	-	440	-	-	-
		3	-	-	-	-	550	-	-	-	930	-	-	-
		6	20	-	-	-	690	-	-	-	780	-	-	-
CHROMIUM	(2)	1	-	-	-	-	770	-	-	-	940	-	-	-
		2	-	-	-	-	820	-	-	-	470	-	-	-
		3	-	-	-	-	940	-	-	-	1100	-	-	-
		6	2	-	-	-	880	-	-	-	490	-	-	-
COPPER	(3)	1	-	-	-	-	-	-	-	-	100	-	-	-
		2	-	-	-	-	-	-	-	-	190	-	-	-
		3	-	-	-	-	-	-	-	-	260	-	-	-
		6	2	-	-	-	190	-	-	-	230	-	-	-
LEAD	(4)	1	ND(<1)	-	-	-	-	-	-	-	-	-	-	-
		2	ND(<1)	-	-	-	-	-	-	-	-	-	-	-
		3	ND(<1)	-	-	-	-	-	-	-	-	-	-	-
		6	1	-	-	-	12	-	-	-	17	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	1	-	-	-	ND(<1)	-	-	-	1	-	-	-
THALLIUM	(7)	1	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		2	3	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		3	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		6	ND(<2)	-	-	-	-	-	-	-	-	-	-	-
NICKEL	(8)	1	ND(<2)	-	-	-	-	-	-	-	9	-	-	-
		2	ND(<2)	-	-	-	-	-	-	-	6	-	-	-
		3	ND(<2)	-	-	-	-	-	-	-	44	-	-	-
		6	1	-	-	-	ND(<1)	-	-	-	18	-	-	-
ARSENIC	(9)	6	4	-	-	-	8	-	-	-	6	-	-	-
SELENIUM	(10)	1	4	-	-	-	11	-	-	-	10	-	-	-
		2	13	-	-	-	8	-	-	-	ND(<6)	-	-	-
		3	4	-	-	-	9	-	-	-	8	-	-	-
		6	5	-	-	-	15	-	-	-	10	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
CADMIUM	(12)	1	-	-	-	-	-	-	-	-	13	-	-	-
		2	-	-	-	-	-	-	-	-	9	-	-	-
		3	-	-	-	-	-	-	-	-	15	-	-	-
		6	ND(<1)	-	-	-	ND(<1)	-	-	-	16	-	-	-
MERCURY	(13)	1	1	-	-	-	ND(<1)	-	-	-	2	-	-	-
		2	6	-	-	-	6	-	-	-	5	-	-	-
		3	1	-	-	-	2	-	-	-	9	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-43 (CONTINUED) CONCENTRATION OF TRACE ELEMENTS AT REFINERY 13, UG/L

PARAMETER		SAMPLE DATE	FINAL EFFLUENT EPA RETA	RADIAN	COMPANY	OTHER
ZINC	(1)	1	590	-	-	-
		2	620	-	-	-
		3	590	-	-	-
		6	700	-	-	-
CHROMIUM	(2)	6	3	-	-	-
COPPER	(3)	6	10	-	-	-
LEAD	(4)	1	26	-	-	-
		2	38	-	-	-
		3	26	-	-	-
		6	50	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-
ANTIMONY	(6)	6	3	-	-	-
THALLIUM	(7)	1	3	-	-	-
		2	7	-	-	-
		3	ND(<1)	-	-	-
		6	ND(<2)	-	-	-
NICKEL	(8)	1	7	-	-	-
		2	7	-	-	-
		3	7	-	-	-
		6	15	-	-	-
ARSENIC	(9)	6	5	-	-	-
SELENIUM	(10)	1	13	-	-	-
		2	10	-	-	-
		3	19	-	-	-
		6	19	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-
MERCURY	(13)	1	1	-	-	-
		2	1	-	-	-
		3	6	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-44 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 14, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (R2)			
		EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<10)	-	-	-	1100	-	-	-	700 H	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	ND(<10)	-	-	-	1100 H	-	-	-	600 H	-	-	-
FLUORANTHENE	(29) 6	ND(<10)	-	-	-	40 F	-	-	-	ND(<10)	-	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	ND(<10)	-	-	-	40 H	-	-	-	ND(<10)	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	1100	-	-	-	700	-	-	-	1100	-	-	-
PHENOL	(53) 6	10	-	-	-	4900	-	-	-	2400	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
F - COMBINED VALUE FOR FLOURANTHENE AND PYRENE
H - THESE COMPOUNDS ARE INDISTINQUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-44 (CONTINUED) CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 14, UG/L

PARAMETER	SAMPLE DATE	FINAL EFFLUENT			
		EPA RETA	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<10)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	ND(<10)	-	-	-
FLUORANTHENE	(29) 6	ND(<10)	-	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	ND(<10)	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	850	-	-	-
PHENOL	(53) 6	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-45 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 14, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER EPA RETA(3)	INTAKE WATER RADIAN	INTAKE WATER COMPANY	INTAKE WATER OTHER	WASTEWATER FEED TO BIOTREATMENT (R1) EPA RETA(3)	WASTEWATER FEED TO BIOTREATMENT (R1) RADIAN	WASTEWATER FEED TO BIOTREATMENT (R1) COMPANY	WASTEWATER FEED TO BIOTREATMENT (R1) OTHER	WASTEWATER FEED TO BIOTREATMENT (R2) EPA RETA(3)	WASTEWATER FEED TO BIOTREATMENT (R2) RADIAN	WASTEWATER FEED TO BIOTREATMENT (R2) COMPANY	WASTEWATER FEED TO BIOTREATMENT (R2) OTHER
ZINC	(1)	1	-	-	-	-	60	-	-	-	44	-	-	-
		2	-	-	-	-	24	-	-	-	87	-	-	-
		3	-	-	-	-	110	-	-	-	92	-	-	-
		6	36	-	-	-	66	-	-	-	53	-	-	-
CHROMIUM	(2)	1	-	-	-	-	820	-	-	-	710	-	-	-
		2	-	-	-	-	790	-	-	-	680	-	-	-
		3	-	-	-	-	1200	-	-	-	930	-	-	-
		6	1	-	-	-	1000	-	-	-	800	-	-	-
COPPER	(3)	6	7	-	-	-	7	-	-	-	3	-	-	-
LEAD	(4)	1	-	-	-	-	420	-	-	-	270	-	-	-
		2	-	-	-	-	160	-	-	-	320	-	-	-
		3	-	-	-	-	430	-	-	-	360	-	-	-
		6	2	-	-	-	278	-	-	-	260	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	1	-	-	-
THALLIUM	(7)	1	-	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		2	-	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		3	-	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		6	ND(<2)	-	-	-	ND(<2)	-	-	-	ND(<2)	-	-	-
NICKEL	(8)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	1	-	-	-
ARSENIC	(9)	6	5	-	-	-	5	-	-	-	ND(<4)	-	-	-
SELENIUM	(10)	1	-	-	-	-	9	-	-	-	5	-	-	-
		2	-	-	-	-	10	-	-	-	13	-	-	-
		3	-	-	-	-	6	-	-	-	7	-	-	-
		6	3	-	-	-	6	-	-	-	9	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	.5	-	-	-	ND(<.2)	-	-	-	ND(<.2)	-	-	-
		2	.4	-	-	-	ND(<.2)	-	-	-	.5	-	-	-
		3	ND(<.5)	-	-	-	.2	-	-	-	1	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-45 (CONTINUED) CONCENTRATION OF TRACE ELEMENTS AT REFINERY 14, UG/L

PARAMETER		SAMPLE DATE	FINAL EFFLUENT			
			EPA RETA(3)	RADIAN	COMPANY	OTHER
ZINC	(1)	6	36	-	-	-
CHROMIUM	(2)	6	1	-	-	-
COPPER	(3)	6	7	-	-	-
LEAD	(4)	6	2	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-
THALLIUM	(7)	1	6	-	-	-
		2	12	-	-	-
		3	5	-	-	-
		6	ND(<2)	-	-	-
NICKEL	(8)	6	ND(<1)	-	-	-
ARSENIC	(9)	6	5	-	-	-
SELENIUM	(10)	1	32	-	-	-
		2	9	-	-	-
		3	7	-	-	-
		6	3	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-
MERCURY	(13)	1	1	-	-	-
		2	ND(<.2)	-	-	-
		3	.5	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
3 - EPA DATA ON THIS SAMPLE POINT ALSO OBTAINED FROM ANALYSIS BY EPA REGION V.

TABLE A-46 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 15, UG/L

PARAMETER	SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
		EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
NAPHTHALENE	(8) 6	ND(<10)	-	-	-	290	-	-	-	ND(<10)	-	-	-
DIETHYL PHTHALATE	(28) 6	ND(<10)	-	-	-	ND(<10)	-	-	-	D(<10)	-	-	-
DI-N-BUTYL PHTHALATE	(31) 6	30	-	-	-	ND(<10)	-	-	-	10	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	950	-	-	-	300	-	-	-	600	-	-	-
PHENOL	(53) 6	ND(<10)	-	-	-	390	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-47 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 15, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
ZINC	(1)	1	-	-	-	-	110	-	-	-	-	-	-	-
		2	-	-	-	-	100	-	-	-	-	-	-	-
		3	-	-	-	-	100	-	-	-	-	-	-	-
		6	25	-	-	-	100	-	-	-	60	-	-	-
CHROMIUM	(2)	6	1	-	-	-	3	-	-	-	1	-	-	-
COPPER	(3)	6	10	-	-	-	6	-	-	-	3	-	-	-
LEAD	(4)	6	2	-	-	-	2	-	-	-	2	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
THALLIUM	(7)	1	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		2	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		3	ND(<1)	-	-	-	ND(<1)	-	-	-	-	-	-	-
		6	ND(<2)	-	-	-	ND(<2)	-	-	-	ND(<2)	-	-	-
NICKEL	(8)	1	-	-	-	-	7	-	-	-	-	-	-	-
		2	-	-	-	-	ND(<2)	-	-	-	-	-	-	-
		3	-	-	-	-	ND(<2)	-	-	-	-	-	-	-
		6	ND(<1)	-	-	-	5	-	-	-	ND(<1)	-	-	-
ARSENIC	(9)	6	ND(<4)	-	-	-	5	-	-	-	ND(<4)	-	-	-
SELENIUM	(10)	1	-	-	-	-	ND(<4)	-	-	-	25	-	-	-
		2	-	-	-	-	ND(<4)	-	-	-	23	-	-	-
		3	-	-	-	-	7	-	-	-	-	-	-	-
		6	2	-	-	-	4	-	-	-	16	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	.7	-	-	-	ND(<.2)	-	-	-	ND(<.2)	-	-	-
		2	.5	-	-	-	.8	-	-	-	ND(<.2)	-	-	-
		3	.7	-	-	-	.8	-	-	-	1	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-48 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 16, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (R2)			
			EPA RETA	RADIAN	COMPANY (11)	OTHER	EPA RETA	RADIAN	COMPANY (11)	OTHER	EPA RETA	RADIAN	COMPANY (11)	OTHER
ACENAPHTHENE	(15)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
FLUORENE	(17)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
N-NITROSODIPHENYLAMINE	(21)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
PHENANTHRENE/ANTHRACENE	(24)	6	D(<10)	-	-	-	30	-	-	-	90 H	-	-	-
DIMETHYL PHTHALATE	(27)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
DIETHYL PHTHALATE	(28)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
FLUORANTHENE	(29)	6	ND(<10)	-	-	-	30 F	-	-	-	ND(<10)	-	-	-
PYRENE	(30)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35)	6	ND(<10)	-	-	-	30	-	-	-	30 H	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37)	6	110	-	-	-	180	-	-	-	300	-	-	-
PHENOL	(53)	6	ND(<10)	-	-	-	420	-	-	-	160	-	-	-
2-4-DIMETHYLPHENOL	(55)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
PENTACHLOROPHENOL	(63)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED, X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
F - COMBINED VALUE FOR FLOURANTHENE AND PYRENE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.
11 - COMPOSITE OF 5 API SEPARATORS AND BIO POND INLET.

TABLE A-48 (CONTINUED) CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 16, UG/L

PARAMETER		SAMPLE DATE	WASTEWATER FEED TO BIOTREATMENT (R3)				WASTEWATER FEED TO BIOTREATMENT (R4)				WASTEWATER FEED TO BIOTREATMENT (R5)			
			EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
ACENAPHTHENE	(15)	6	ND(<10)	-	-	-	50	-	-	-	ND(<10)	-	-	-
FLUORENE	(17)	6	ND(<10)	-	-	-	80	-	-	-	ND(<10)	-	-	-
N-NITROSODIPHENYLAMINE	(21)	6	ND(<10)	-	-	-	D(<10)A	-	-	-	ND(<10)	-	-	-
PHENANTHRENE/ANTHRACENE	(24)	6	ND(<10)	-	-	-	230 H	-	-	-	ND(<10)	-	-	-
DIMETHYL PHTHALATE	(27)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
DIETHYL PHTHALATE	(28)	6	ND(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
FLUORANTHENE	(29)	6	ND(<10)	-	-	-	20 HF	-	-	-	ND(<10)	-	-	-
PYRENE	(30)	6	ND(<10)	-	-	-	20 HF	-	-	-	ND(<10)	-	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35)	6	50 H	-	-	-	40 H	-	-	-	ND(<10)	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37)	6	50	-	-	-	600	-	-	-	ND(<10)	-	-	-
PHENOL	(53)	6	ND(<10)	-	-	-	16000	-	-	-	ND(<10)	-	-	-
2-4-DIMETHYLPHENOL	(55)	6	ND(<10)	-	-	-	650	-	-	-	ND(<10)	-	-	-
PENTACHLOROPHENOL	(63)	6	ND(<10)	-	-	-	850	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
A - POSSIBLE IDENTIFICATION
F - COMBINED VALUE FOR FLOURANTHENE AND PYRENE
H - THESE COMPOUNDS ARE INDISTINGUISHABLE IN THIS SAMPLE AS ANALYZED BY THE EPA PROTOCOL.

TABLE A-48 (CONTINUED) CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 16, UG/L

PARAMETER	SAMPLE DATE	WASTEWATER FEED TO BIOTREATMENT (R6)				FINAL EFFLUENT			
		EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
ACENAPHTHENE	(15) 6	ND(<10)	-	-	-	ND(<10)	-	-	-
FLUORENE	(17) 6	ND(<10)	-	-	-	ND(<10)	-	-	-
N-NITROSODIPHENYLAMINE	(21) 6	ND(<10)	-	-	-	ND(<10)	-	-	-
PHENANTHRENE/ANTHRACENE	(24) 6	ND(<10)	-	-	-	D(<10)	-	-	-
DIMETHYL PHTHALATE	(27) 6	ND(<10)	-	-	-	3	-	-	-
DIETHYL PHTHALATE	(28) 6	ND(<10)	-	-	-	30	-	-	-
FLUORANTHENE	(29) 6	ND(<10)	-	-	-	ND(<10)	-	-	-
PYRENE	(30) 6	ND(<10)	-	-	-	ND(<10)	-	-	-
CHRYSENE/BENZ(A)ANTHRACENE	(35) 6	ND(<10)	-	-	-	ND(<10)	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37) 6	210	-	-	-	190	-	-	-
PHENOL	(53) 6	Q(7000)	-	-	-	ND(<10)	-	-	-
2-4-DIMETHYLPHENOL	(55) 6	750	-	-	-	ND(<10)	-	-	-
PENTACHLOROPHENOL	(63) 6	ND(<10)	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-49 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 16, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT (R1)				WASTEWATER FEED TO BIOTREATMENT (R2)			
			EPA RETA(4)	RADIAN	COMPANY (11)	OTHER	EPA RETA(4)	RADIAN	COMPANY (11)	OTHER	EPA RETA(4)	RADIAN	COMPANY (11)	OTHER
ZINC	(1)	1	-	-	-	-	120	-	-	-	290	-	-	-
		2	-	-	-	-	250	-	-	-	2100	-	-	-
		3	-	-	-	-	420	-	-	-	680	-	-	-
		6	54	-	-	-	320	-	-	-	740	-	-	-
CHROMIUM	(2)	1	-	-	-	-	9	-	940	-	450	-	-	-
		2	-	-	-	-	100	-	940	-	1100	-	-	-
		3	-	-	-	-	76	-	1300	-	390	-	-	-
		6	1	-	ND(<30)	-	-	-	-	-	780	-	-	-
COPPER	(3)	6	1	-	-	-	2	-	-	-	7	-	-	-
LEAD	(4)	1	-	-	-	-	-	-	-	-	190	-	-	-
		2	-	-	-	-	-	-	-	-	2000	-	-	-
		3	-	-	-	-	-	-	-	-	380	-	-	-
		6	2	-	-	-	4	-	-	-	870	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
THALLIUM	(7)	1	ND(<1)	-	-	-	ND(<1)	-	-	-	3	-	-	-
		2	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		3	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		6	ND(<2)	-	-	-	ND(<2)	-	-	-	3	-	-	-
NICKEL	(8)	6	1	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ARSENIC	(9)	6	3	-	-	-	3	-	-	-	5	-	-	-
SELENIUM	(10)	1	-	-	-	-	7	-	-	-	16	-	-	-
		2	-	-	-	-	16	-	-	-	12	-	-	-
		3	-	-	-	-	ND(<4)	-	-	-	14	-	-	-
		6	3	-	-	-	5	-	-	-	8	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-	ND(<1)	-		-	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	.1	-	-	-	3	-	-	-	.1	-	-	-
		2	.2	-	-	-	ND(<.1)	-	-	-	5	-	-	-
		3	2	-	-	-	1	-	-	-	ND(<.1)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
O(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.
4 - PHENOLICS AND CYANIDE DATA FROM RSKERL.
11 - COMPOSITE OF 5 API SEPARATORS AND BIO POND INLET.

TABLE A-49 (CONTINUED) CONCENTRATION OF TRACE ELEMENTS AT REFINERY 16, UG/L

PARAMETER		SAMPLE DATE	WASTEWATER FEED TO BIOTREATMENT (R3) EPA RETA(4)	RADIAN	COMPANY	OTHER	WASTEWATER FEED TO BIOTREATMENT (R4) EPA RETA(4)	RADIAN	COMPANY	OTHER	WASTEWATER FEED TO BIOTREATMENT (R5) EPA RETA(4)	RADIAN	COMPANY	OTHER
ZINC	(1)	1	150	-	-	-	340	-	-	-	600	-	-	-
		2	210	-	-	-	290	-	-	-	740	-	-	-
		3	280	-	-	-	620	-	-	-	520	-	-	-
		6	260	-	-	-	560	-	-	-	760	-	-	-
CHROMIUM	(2)	1	830	-	-	-	1500	-	-	-	2200	-	-	-
		2	1200	-	-	-	1300	-	-	-	4900	-	-	-
		3	660	-	-	-	1700	-	-	-	1800	-	-	-
		6	570	-	-	-	1900	-	-	-	3600	-	-	-
COPPER	(3)	6	2	-	-	-	10	-	-	-	182	-	-	-
LEAD	(4)	6	2	-	-	-	12	-	-	-	2	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-	1	-	-	-	ND(<1)	-	-	-
THALLIUM	(7)	1	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		2	ND(<1)	-	-	-	ND(<1)	-	-	-	4	-	-	-
		3	ND(<1)	-	-	-	ND(<1)	-	-	-	6	-	-	-
		6	ND(<2)	-	-	-	ND(<2)	-	-	-	ND(<2)	-	-	-
NICKEL	(8)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	1	-	-	-
ARSENIC	(9)	6	3	-	-	-	3	-	-	-	9	-	-	-
SELENIUM	(10)	1	17	-	-	-	25	-	-	-	7	-	-	-
		2	13	-	-	-	24	-	-	-	29	-	-	-
		3	31	-	-	-	4	-	-	-	19	-	-	-
		6	6	-	-	-	11	-	-	-	23	-	-	-
SILVER	(11)	6	1	-	-	-	2	-	-	-	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	7	-	-	-
MERCURY	(13)	1	ND(<.1)	-	-	-	.2	-	-	-	ND(<.1)	-	-	-
		2	1	-	-	-	5	-	-	-	.2	-	-	-
		3	6	-	-	-	2	-	-	-	2	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-49 (CONTINUED) CONCENTRATION OF TRACE ELEMENTS AT REFINERY 16, UG/L

PARAMETER		SAMPLE DATE	WASTEWATER FEED TO BIOTREATMENT (R6) EPA RETA(4)	RADIAN	COMPANY	OTHER	FINAL EFFLUENT EPA RETA(4)	RADIAN	COMPANY	OTHER
ZINC	(1)	6	ND(<10)	-	-	-	62	-	-	-
CHROMIUM	(2)	1	9	-	-	-	150	-	-	-
		2	5	-	-	-	27	-	-	-
		3	6	-	-	-	27	-	-	-
		6	22	-	-	-	54	-	120	-
COPPER	(3)	6	2	-	-	-	32	-	-	-
LEAD	(4)	6	3	-	-	-	9	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-	ND(<1)	-	-	-
THALLIUM	(7)	1	ND(<1)	-	-	-	ND(<1)	-	-	-
		2	ND(<1)	-	-	-	ND(<1)	-	-	-
		3	ND(<1)	-	-	-	ND(<1)	-	-	-
		6	ND(<1)	-	-	-	ND(<2)	-	-	-
NICKEL	(8)	6	ND(<1)	-	-	-	3	-	-	-
ARSENIC	(9)	6	ND(<2)	-	-	-	ND(<4)	-	-	-
SELENIUM	(10)	1	20	-	-	-	20	-	-	-
		2	10	-	-	-	27	-	-	-
		3	18	-	-	-	16	-	-	-
		6	22	-	-	-	12	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-	ND(<1)	-	-	-
CADMIUM	(12)	6	ND(<1)	-	-	-	ND(<1)	-	-	-
MERCURY	(13)	1	2	-	-	-	ND(<.1)	-	-	-
		2	6	-	-	-	6	-	-	-
		3	3	-	-	-	4	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE
4 - PHENOLICS AND CYANIDE DATA FROM RSKERL.

TABLE A-50 CONCENTRATION OF PRIORITY LIQUID/LIQUID EXTRACTABLE ORGANICS AT REFINERY 17, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
DIMETHYL PHTHALATE	(27)	6	20	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
DIETHYL PHTHALATE	(28)	6	D(<10)	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
DI-N-BUTYL PHTHALATE	(31)	6	20	-	-	-	ND(<10)	-	-	-	ND(<10)	-	-	-
BIS(2-ETHYLHEXYL)PHTHALATE	(37)	6	1100	-	-	-	320	-	-	-	2000	-	-	-
PHENOL	(53)	6	10	-	-	-	60	-	-	-	ND(<10)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
Q(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

TABLE A-51 CONCENTRATION OF TRACE ELEMENTS AT REFINERY 17, UG/L

PARAMETER		SAMPLE DATE	INTAKE WATER				WASTEWATER FEED TO BIOTREATMENT				FINAL EFFLUENT			
			EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER	EPA RETA	RADIAN	COMPANY	OTHER
ZINC	(1)	1	-	-	-	-	330	-	-	-	380	-	-	-
		2	-	-	-	-	470	-	-	-	360	-	-	-
		3	-	-	-	-	640	-	-	-	350	-	-	-
		6	35	-	-	-	470	-	-	-	340	-	-	-
CHROMIUM	(2)	6	1	-	-	-	1	-	-	-	2	-	-	-
COPPER	(3)	1	-	-	-	-	60	-	-	-	-	-	-	-
		2	-	-	-	-	140	-	-	-	-	-	-	-
		3	-	-	-	-	60	-	-	-	-	-	-	-
		6	120	-	-	-	210	-	-	-	180	-	-	-
LEAD	(4)	6	2	-	-	-	10	-	-	-	15	-	-	-
BERYLLIUM	(5)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ANTIMONY	(6)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	1	-	-	-
THALLIUM	(7)	1	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		2	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		3	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
		6	ND(<2)	-	-	-	ND(<2)	-	-	-	ND(<2)	-	-	-
NICKEL	(8)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
ARSENIC	(9)	1	-	-	-	-	480	-	-	-	790	-	-	-
		2	-	-	-	-	460	-	-	-	900	-	-	-
		3	-	-	-	-	460	-	-	-	680	-	-	-
		6	7	-	-	-	440	-	-	-	800	-	-	-
SELENIUM	(10)	1	ND(<6)	-	-	-	9	-	-	-	11	-	-	-
		2	6	-	-	-	7	-	-	-	10	-	-	-
		3	10	-	-	-	6	-	-	-	22	-	-	-
		6	6	-	-	-	10	-	-	-	20	-	-	-
SILVER	(11)	6	ND(<1)	-	-	-	ND(<1)	-	-	-	ND(<1)	-	-	-
CADMIUM	(12)	1	-	-	-	-	-	-	-	-	ND(<1)	-	-	-
		2	-	-	-	-	-	-	-	-	ND(<1)	-	-	-
		3	-	-	-	-	-	-	-	-	ND(<1)	-	-	-
		6	ND(<1)	-	-	-	ND(<1)	-	-	-	5	-	-	-
MERCURY	(13)	1	-	-	-	-	6	-	-	-	6	-	-	-
		2	1	-	-	-	ND(<.2)	-	-	-	2	-	-	-
		3	6	-	-	-	ND(<.2)	-	-	-	ND(<.2)	-	-	-

D(X) - COMPOUND WAS DETECTED AT SOME CONCENTRATION LESS THAN X, BUT THE CONCENTRATION COULD NOT BE QUANTIFIED.
G(X) - COMPOUND WAS DETECTED AT A LEVEL GREATER THAN X.
ND(X)- COMPOUND WAS NOT DETECTED; X EQUALS THE LOWEST LIMIT OF SENSITIVITY OF THE METHOD FOR THAT SAMPLE.

APPENDIX B

STATISTICAL EVALUATION OF DATA

APPENDIX B
STATISTICAL EVALUATION OF DATA

1.0 INTRODUCTION

This appendix presents detailed summaries and discussions concerning the statistical analysis of the analytical results for the Priority Pollutants as reported in Appendix A. Blank sample analyses, duplicate analyses, recovery data, and laboratory comparisons are presented and discussed.

2.0 BLANK SAMPLE ANALYSES

Field blanks associated with samples from a particular refinery or a particular location within a refinery were analyzed by EPA laboratories, Radian, and company laboratories. Analyses of blanks were performed as a check on potential contamination of samples. Table B-1 contains a summary of the field blank analyses. The location which the blank sample represents is given as well as the data reported for the corresponding location by the laboratory that analyzed the blank. Most field blanks were associated with a particular location within a refinery, but some of the blanks analyzed by Radian were composites from all sampled locations in the refinery.

A review of Table B-1 indicates contamination in many of the blanks. Often there is greater concentration of a component in the blank than in the associated samples. When these high levels of contamination are reported, blank correction of sample concentrations is impossible. Methylene chloride, for instance, was found in all except one of the blanks with reported concentrations.

TABLE B-1. ANALYSES OF FIELD BLANK SAMPLES - VOLATILE ORGANICS (µg/ℓ)

Refinery	Location	Date	Laboratory	Parameters Detected In Blank Samples	Reported Blank Result	Sample Results Associated With Blank
1	1	6	EPA	Methylene chloride	35	50
1	2	6	EPA	Methylene chloride	70	10
1	2	6	EPA	Methylene chloride	40	50
2	0	1	Company	Methylene chloride	D (<1)	0.6, 1, 1
2	0	3	Company	Methylene chloride 1,2 Dichloroethane	D (<1) D (<0.5)	0.4, 0.9, 0.5 ND (<1), 51, D (<.5)
2	0	6	Radian	Methylene chloride 1,1,1 Tichloroethane Benzene Toluene Ethylbenzene	50 3 2 5 2	10, 30, 300, D (<5) 2, ND (<.3), 10, 3, 2, 3 1, 50, 30, 1, 1, 30 6, 130, 50, 3, 3, 60 2, 70, 100, 1, 1, 20
2	1	6	EPA	Methylene chloride	10	G (100)
2	3	6	EPA	Methylene chloride Benzene	40 10	ND (<40) 6
2	2	6	EPA	Methylene chloride	30	G (100)
3	1	6	EPA	Methylene chloride Chloroform	D (<5) 70	G (50) 70
3	2	6	EPA	Methylene chloride	D (<5)	G (50)
3	3	6	EPA	Methylene chloride Chloroform	D (<5) D (<5)	G (50) D (<5)
5	1	1	Company	Methylene chloride	800	32
5	1	3	Company	Methylene chloride	11	80
5	2	1	Company	Methylene chloride	740	10
5	2	2	Company	Methylene chloride	280	16
5	2	3	Company	Methylene chloride	25	10
5	3	1	Company	Methylene chloride	365	44
5	3	3	Company	Methylene chloride	179	10
5	1	6	EPA	Methylene chloride	G (100)	50
5	2	6	EPA	Methylene chloride	G (100)	10
5	3	6	EPA	Methylene chloride	G (100)	10
6	1	6	EPA	Methylene chloride	50	D (<10)
6	2	6	EPA	Methylene chloride	10	70
6	3	6	EPA	Methylene chloride	50	D (<10)
7	3	6	Company	Benzene Toluene Ethylbenzene	33 41 9	ND (<1) ND (<1) ND (<1)
7	0	6	Radian	Methylene chloride	38, 78	6, 9, 10, 20, 23, 49 ND (<.2), 4, 4
				Chloroform	1, 2	29, 31, 37, 2, 7, 3 16, 14, 10
				Trichloroethylene	1	1, D (<1), 1, 2, 4, 5, D (<1), 1, D (<1)
				Toluene	1, 1	3, D (<1) (5 times); 4200, 820, 2900
				Ethylbenzene	1, 1	D (<1) (6 times), 440, 250, 460
9	0	6	Radian	Methylene chloride	63	19, 9, 12
9	1	6	Radian	Methylene chloride	7	19
9	2	6	Radian	Methylene chloride	6	9
9	3	6	Radian	Methylene chloride Toluene	6 2	12 D (<1)
11	1	6	Radian	Methylene chloride Trichloroethylene	12 1	19 1
11	2	6	Radian	Methylene chloride Trichloroethylene Toluene	22 1 1	4.9 D (<1) 44,000
11	3	6	Radian	Methylene chloride Trichloroethylene Toluene	19 1 1	8 D (<1) D (<1)

CODE **LOCATION**

1 Intake water
2 Wastewater feed to biotreatment
3 Effluent
0 Blank associated with no particular location within the refinery

DATE

1 First day of sampling
2 Second day of sampling
3 Third day of sampling
6 Composite sample from Days 1, 2, and 3

3.0 SPIKING AND RECOVERY STUDIES

Samples previously analyzed were spiked with selected compounds to determine the expected recoveries for samples analyzed. This spiking data was reported in Tables A-4, A-5 and A-8. Table B-2 summarizes the results from these studies. Average recoveries for trace elements ranged from 72 to 139% for the different species. Recovery ranges were quite variable often differing by more than 50%. Ninety percent confidence intervals for mean recovery bracketed 100% for all species except Cadmium (103-116%) for Radian data. EPA recovery data for mercury showed an 85% average recovery with a confidence interval of 80 to 90% recovery.

The recovery data for the liquid/liquid extractables are divided into three compound groups: PNAs, phenols, and phthalates; and into low range spikes and high range spikes. The PNA data indicate that recoveries decline significantly for spike concentrations less than 30 ppb. The recovery data for the phenols does not appear to be affected by the level of spikes considered. Overall recovery for phenols was 64% (90% confidence interval of 51-77%). Phthalate ester recovery data reported in Appendix A was quite variable (recoveries of 4 and 6.5% for low level spikes and from 25 to 300% for high level spikes).

TABLE B-2. SUMMARY OF RECOVERY STUDIES

Element	Number of Spikes	Range of Spike Concentrations, (ppb)	Range of Recoveries	Average Percent Recovery	90% Confidence Interval for Mean Recovery
I. ELEMENTAL ANALYSIS (Data from Table A-8)					
Zinc	3	100-500	101-161%	129	76-180
Chromium	3	40-100	98-146%	115	68-164
Copper	3	33-100	86-112%	101	77-125
Lead	3	5-100	61-181%	139	26-252
Beryllium	3	1-2	70-130%	100	50-151
Antimony	3	10-100	42-131%	101	15-187
Thallium	3	50-100	46-126%	77	5-149
Nickel	3	10-25	77-103%	92	70-115
Arsenic	3	50-100	94-117%	105	87-126
Selenium	3	5-100	46-94%	72	32-113
Silver	3	1.7-5	98-193%	133	45-221
Cadmium	3	2-10	106-114%	109	103-116
Mercury	3	.05-5	34-111%	79	15-140
II. EPA REPORTED RECOVERY DATA - MERCURY					
Mercury	10	0.3-0.5	78-97%	85	80-90

III. LIQUID/LIQUID EXTRACTABLE ORGANICS (Data from Table A-4)

	Low Spikes			High Spikes		
Compound	Number	Spikes (ppb)	Average Percent Recovery	Number	Range of Spikes (ppb)	Average Percent Recovery
PNA						
Naphthalene	2	4.6, 18	56%	3	74 - 210	69%
Fluorene	2	5.1, 18	66%	3	54 - 160	103%
Phenanthrene	2	5, 20	72%	3	78 - 220	103%
Pyrene	2	7.3, 23	63%	3	33 - 95	89%
ALL	8	4.6 - 23	64%	12	33 - 220	91%
90% Confidence Interval for Mean Recovery			54 - 74%			78 - 104%
Phenols						
Phenol	2	8.5, 29	62%	3	120 - 330	43%
2-Chlorophenol	2	3.6, 14	92%	3	84 - 240	66%
ALL	4	3.6 - 29	77%	6	84 - 330	54%
90% Confidence Interval for Mean Recovery			55 - 99%			38 - 71%
Phthalates						
Di-n-butyl	0	--	--	3	140 - 380	127%
bis(2-Ethylhexyl)	0	--	--	3	220 - 610	85%
Butyl benzyl	2	6.2, 25	5%	0	--	--
ALL	2	6.2 - 25	5%	6	140-610	106%
90% Confidence Interval for Mean Recovery			0 - 13%			25 - 187%

4.0 REPEATED ANALYSES OF SAMPLES

Duplicate analysis of selected samples was done by some of the company laboratories and Spectrix Laboratory for the priority volatile organics and by some of the company laboratories for the liquid/liquid extractable organics. The analytical results from the samples are given in Table B-3. The data under the heading, "Analysis I," are those reported in the tables in Appendix A.

The percent difference reported in Table B-3 when the results are quantified is computed as follows:

$$\text{Percent Difference} = \frac{|\text{Analysis I} - \text{Repeat Analysis}|}{(\text{Analysis I} + \text{Repeat Analysis})/2} \times 100$$

This statistic is equivalent to $\sqrt{2}$ times the estimated coefficient of variation or relative standard deviation. Since the reported concentrations range from 0.1 µg/ℓ to 1200 µg/ℓ, a relative standard is needed to compare the repeatability of the test methods. The percent differences in Table B-3 range from 0 to 80% for the volatile organics and from 0 to 105% for the liquid/liquid extractable organics. There is not enough replicate data available to compare the differences for individual parameters.

The individual percent differences can be pooled to estimate an overall relative standard deviation for the test methods. This estimate is computed by averaging the square of the individual percent differences, dividing by two and then taking the square root to obtain an estimate of the relative standard deviation. The following are calculated from the data in Table B-3.

TABLE B-3. DUPLICATE SAMPLE ANALYSIS STUDIES

EXXON DATA - REFINERIES 2, 7, 9

TABLE I - PRIORITY VOLATILE ORGANICS (ug/ℓ)

Parameter	Analysis I	Repeat Analyses	Percent Difference
Methylene chloride	0.6	ND (<1)	-
	1.0	1.0	0
	0.9	D (<1)	-
	1.0	1.0	0
	D (<1)	ND (<1)	-
	0.06	ND (<.05)	-
Chloroform	22	22	0
	21	21	0
	D (<1)	ND (<1)	-
	7	7	0
	D (<0.5)	ND (<1)	-
	ND (<1)	0.09	
1,2 - Dichloroethane	14	12	15
	51	51	0
Benzene	5,000	6,000, 5,000	18, 0
	3	5	50
	4,000	4,000, 4,000	0, 0
1,1,2,2 - Tetrachloroethane	2	1	67
	4	5	22
Toluene	9,000	12,000, 7,000	29, 25
	10	20	67
	7,000	6,000, 7,000	15, 0
Ethylbenzene	70	70, D (<2)	0, -
	D (<5)	D (<50)	-
	D (<70)	D (<70)	-

AVERAGE PERCENT DIFFERENCE = 15.4%
MEDIAN PERCENT DIFFERENCE = 0%

TABLE II - POLYNUCLEAR AROMATIC HYDROCARBONS (ug/ℓ)

Parameter	Analysis I	Repeat Analyses	Percent Difference
Naphthalene	400	1,000; 400	86,0
Fluorene	7	ND (<3)	-
	5	16	105
Phenanthrene	28	33	16
	2.7	2.9	7
	32	51	46
Anthracene	0.1	ND (<.1)	-
Fluoranthene	1.7	4.6	92
	2	2.3	14
	0.3	0.2	40
	0.1	0.1	0
Pyrene	4.1	5.3	26
	6.4	7.5	16
	1.0	0.8	22
	1.1	0.4	93
Chrysene	2.0	1.9	5
	0.3	0.2	0
	0.2	0.2	0
	2.6	3.8	38
Benzo(a)anthracene	1.4	1.4	0
	0.1	0.1	0
	0.08	0.07	13
	1.4	1.7	19
Benzo(b)fluoranthene	0.3	ND (<.1)	-
Benzo(k)fluoranthene	0.3	ND (<.3)	-
Benzo(a)pyrene	0.8	0.9	12
	1.1	1.2	9
	0.1	0.2	67
	0.1	0.1	0
Benzo(g,h,i)perylene	0.4	0.5	22
	0.6	0.7	15
	0.2	0.2	0
	0.2	0.2	0

AVERAGE PERCENT DIFFERENCE = 25.4%
MEDIAN PERCENT DIFFERENCE = 14%

TABLE B-3. DUPLICATE SAMPLE ANALYSIS STUDIES continued

TABLE III - DUPLICATE SAMPLE ANALYSIS STUDIES
SPECTRIX CORPORATION - REFINERY 5, (µg/ℓ)

Parameter	Analyses I	Repeat Analyses	Percent Difference
Methylene chloride	29	23	23
Chloroform	ND (<1)	34	-
1,1,1-Trichloroethane	15	18	18
Carbon Tetrachloride	2	4	67
Trichloroethylene	ND (<1)	9	-
Benzene	240	105	78
1,1,2,2-Tetrachloroethene	ND (<1)	6	-
Toluene	80	186	80

AVERAGE PERCENT DIFFERENCE = 53.2%
MEDIAN PERCENT DIFFERENCE = 67%

	Relative Standard Deviation	Range of Concentration
Volatile Organics	25.7%	0.06-12000 µg/ℓ
Liquid/Liquid Extractable Organics	28.5%	0.07- 1000 µg/ℓ

The relative standard deviation is about 25-30% for both types of analyses. The estimate of the repeatability of a test method is often computed as 2.8 times the standard deviation, and interpreted as the maximum difference expected (95% of the time) between two test results run under the same conditions in the same laboratory. For the organics analyses, the repeatability would be about 80%. Only four of the 55 quantified differences in Table B-2 exceed this 80% repeatability. When it is necessary to report the standard deviation as a percentage of the sample concentration, it is important to carefully interpret the repeatability statistic. Eighty percent of 1.0 µg/ℓ is only 0.8 µg/ℓ while 80% of 5000 µg/ℓ is 4000 µg/ℓ.

Estimates of analytical repeatability can also be derived from the spiked sample studies reported in Section 3. Analysis of this data indicates that for the PNAs, the within lab standard deviation is about 16% for concentrations greater than 40 ppb, while the standard deviation increases to 45% for samples at the one ppb level. For the phenols, the standard deviation is about 35% for samples greater than 20 ppb and increases to about 70% for samples at one ppb.

Estimates from the EPA-reported quality control study of mercury show that the standard deviation is about 10% or 0.04 ppb for samples in the 0.3 to 0.5 ppb range.

In a previously reported study,[12] the repeatability of the GC/UV method of PNA analyses was found to be about 75% of the mean for concentrations up to 3 ppb and about 54% of the mean for concentrations from 3 to 200 ppb. The accuracy of the GV/UV method was evaluated by comparison of results from different methods (GC/UV vs. thin-layer chromatography, HPLC, etc.) and analyses of spiked samples. A standard deviation calculated from the differences between the methods was about .3 ppb for concentrations less than 2 ppb and 20% of the mean for concentrations between 2 and 20 ppb.

5.0 LABORATORY COMPARISONS

An important aspect of analytical methods which are used by different laboratories is the ability to reproduce test results from one laboratory to another. The analytical data presented in Appendix A are arranged in a format to facilitate comparison of the data from different investigating laboratories. From a detailed study of these tables, one can determine the reproducibility of the test methods, but the comparison of the laboratories is complicated by a number of factors:

- Differences in samples analyzed by the reporting laboratories: For instance, the EPA laboratory may have analyzed a three-day composite while the company laboratory analyzed individual samples from Day 1 and Day 2. Differences between the results could be due to different true sample concentrations as well as to differences between the laboratories.

- Detection limits and reporting formats. It is difficult to make a meaningful comparison between the laboratories if one reports the sample results as ">50" and the other laboratory as "<100".

- Lack of a well-designed experiment to isolate the various sources of variation in the analytical data. Differences between analytical results in two laboratories may be due to any or all of the following sources:

  - repeatability of the test method,
  - interferences from sample contamination,

- differences in sampling and compositing procedures,
- variability of recoveries,
- age of sample at time of analysis,
- application of different analytical methodologies, and
- actual interlaboratory variability of the test method.

In spite of these complications, an attempt was made to summarize the interlaboratory differences in the analytical data. Availability of data for which two or more laboratories made determinations on portions of the same sample or on samples representing the same time period and location is summarized below:

	Refineries from which Data is Available		
Comparisons	Volatile Organics	Liquid/Liquid Extractable Organics	Trace Elements
EPA Labs vs. Radian	2	2	2,7,9
EPA Labs vs. Company Labs	2	2,6	2,7,9,11,16
Radian vs. Company Labs	2,7,9	2,7,9	2,7,9
Radian vs. Other Contract Labs		7	

5.1 Tabled Comparisons

A first attempt to compare the different laboratories was based on the following assumptions and conventions:

- Only data with at least one laboratory having a detected result were considered.
- Data for which it was not possible to determine which laboratory was reporting

"higher" or "lower" was called inconclusive. Examples of reported data which would be classified as inconclusive are:

Lab A	Lab B
D(<5)	ND(<10)
10	ND(<20)
D(<5)	4.2
G(100)	1000

- Data from different types of samples (composite versus individual day samples) were not compared unless the composite analyzed by one laboratory was formed from only the individual day samples analyzed by another laboratory. For example, if Lab A analyzed a composite sample from Days 1, 2, and 3, and Lab B analyzed individual samples only on Day 1 and Day 3, no comparison was made. This approach minimizes the effect of different sample types in the comparisons. When comparisons could be made, the individual day samples were averaged for comparison with the composite results. (If one or more individual day result was reported as ND(<X) or D(<X), the median of the individual values was used.)

- Some differences could not be quantified even when it was clear that one laboratory was reporting higher than the other. For example,

Lab A	Lab B	
D(<5)	10.0	(Lab B higher)
ND(<50)	60.0	(Lab B higher)
G(100)	80.0	(Lab A higher)

Using these conventions, Tables B-4 (Volatile Organics), B-5 (Liquid/Liquid Extractable Organics) and B-6 (Trace Elements) were developed from the reported analytical data in Appendix A.

In these tables, laboratories are compared two at a time. Each suitable (satisfying the assumed conventions given above) comparison between two laboratories was classified as:

I Inconclusive
II Second laboratory higher (or first laboratory lower), or
III Second laboratory lower (or first laboratory higher).

The assignment of a laboratory as "first" laboratory or "second" laboratory is arbitrary and does not affect the interpretation of the laboratory comparisons. The II and III classifications are further classified as:

- Not quantifiable
- ≤75% low (or high)
- >75% low (or high).

"Not quantifiable" comparisons are those in which one of the laboratories is clearly reporting higher (or lower) results than the other laboratory, but it is not obvious how much higher (or lower). For instance, Lab A reports ND(<10) and Lab B reports 15.0. Clearly Lab B is reporting a larger result (Lab B is higher), but one cannot determine how much higher from the data given.

TABLE B-4. VOLATILE ORGANICS (µg/ℓ) - LABORATORY COMPARISONS

Comparison Lab 1 vs. Lab 2	Radian vs. EPA Labs Refinery 2		Radian vs. Company Refineries 2, 7, 9		EPA Labs vs. Company Refinery 2	
	Number	Percent	Number	Percent	Number	Percent
Inconclusive	13	62%	21	23%	16	61%
Second Lab High:	5	24%	18	20%	4	16%
Not Quantifiable	1	5%	2	2%	1	4%
≤75% High	1	5%	5	6%	1	4%
>75% High	3	14%	11	12%	2	8%
Second Lab Low:	3	14%	51	57%	6	23%
Not Quantifiable	--	--	20	22%	--	--
≤75% Low	3	14%	5	6%	--	--
>75% Low	--	--	26	29%	6	23%
Total Comparisons	21	100%	90	100%	26	100%

COMPARISONS WITH DIFFERENCES GREATER THAN 75%

Parameter	Radian	EPA	Percent Difference
6	10	G(100)	>180%
1	ND(<10)	G(100)	>180%
22	20	90	127%

Parameter	Radian	Company	Percent Difference
6	10	0.46	182%
22	1	3	100%
6	30	1	187%
6	300	0.9	199%
11	ND(<0.3)	22	>195%
12	ND(<5)	14	> 95%
13	10	ND(<1)	>164%
24	ND(<0.4)	1	> 86%
24	ND(<0.4)	4	>164%
8	10	ND(<1)	>164%
13	3	ND(<1)	>100%
13	3	ND(<1)	>100%
18	3	ND(<1)	>100%
22	10.7	3	112%
6	30.7	ND(<1)	>187%
11	4	ND(<1)	>120%
18	3.7	ND(<1)	>115%
22	3260	8400	88%
24	5	ND(<1)	>133%
26	2640	8500	105%
6	4	ND(<1)	>120%
6	4	ND(<1)	>120%
11	16	ND(<1)	>176%
11	14	ND(<1)	>173%
11	10	ND(<1)	>164%
26	55	2000	189%
28	5	100	181%
6	12	D(<0.5)	>184%
1	ND(<10)	17000	200%
6	150	D(<1)	>198
6	190	D(<1)	>198%
22	20	4000	198%
6	60	0.5	197%
8	10	ND(<1)	>164%
11	10	ND(<1)	>164%
13	6	ND(<1)	>144%
26	50	7000	197%

Parameter	EPA	Company	Percent Difference
6	G(100)	0.46	>198%
6	G(100)	0.96	>196%
12	ND(<10)	25	> 86%
19	107	ND(<1)	>196%
28	ND(<10)	70	>150%
26	35	10	111%
6	G(100)	D(<1)	>196%
22	90	4000	191%

TABLE B-5. LIQUID/LIQUID EXTRACTABLE ORGANICS (µg/ℓ) - LABORATORY COMPARISONS

Comparison Lab 1 vs. Lab 2	Radian vs. EPA Labs Refinery 2		Radian vs. Company Refineries 2, 7, 9		EPA Labs vs. Company Refineries 2, 6	
	Number	Percent	Number	Percent	Number	Percent
Inconclusive	12	31%	23	33%	31	51%
Second Lab High:	9	23%	21	29%	18	30%
Not Quantifiable	--	--	6	8%	3	5%
≤75% High	1	2%	3	4%	4	6%
>75% High	8	21%	12	17%	11	19%
Second Lab Low:	18	46%	27	38%	12	20%
Not Quantifiable	3	8%	3	4%	--	--
≤75% Low	2	5%	3	4%	4	6%
>75% Low	13	33%	21	30%	8	13%
Total Comparisons	39	100%	71	100%	61	100%

COMPARISONS WITH DIFFERENCES GREATER THAN 75%

Parameter	Radian	EPA	Percent Difference
24	3	ND(<1)	>100%
28	20	ND(<1)	>181%
31	20	ND(<1)	>181%
37	8	ND(<1)	>178%
14	ND(<0.1)	87	>199%
15	9	522	193%
17	30	ND(<1)	>187%
29	1	7.5	153%
30	3	16	137%
31	10	ND(<1)	>164%
55	71	680	162%
28	7	ND(<1)	>150%
31	10	ND(<1)	>164%
8	230	27	158%
24	2	0.6	108%
30	0.7	D(<0.1)	>150%
31	45	ND(<1)	>196%
34	6	ND(<1)	>143%
37	6	ND(<1)	>143%
53	13	40	102%
55	8	G(100)	>170%

Parameter	Radian	Company	Percent Difference
30	0.2	ND(<0.03)	>148%
36	0.3	ND(<0.02)	>175%
38	0.1	ND(<0.01)	>164%
15	9	200	183%
17	30	7	124%
36	9	2	127%
38	ND(<0.2)	1.4	171%
42	ND(<0.1)	0.8	178%
8	ND(<0.1)	4	190%
15	ND(<0.1)	40	199%
29	ND(<0.1)	0.3	100%
8	230	D(<50)	>129%
29	0.2	0.04	133%
28	4	ND(<1)	>120%
8	1100	5200	130%
17	62	ND(<1)	>194%
24	99	ND(<1)	>196%
28	5.5	ND(<1)	>138%
29	23	ND(<1)	>183%
30	6.9	ND(<1)	>142%
37	2.9	ND(<1)	> 97%
42	4.4	ND(<1)	>126%
28	5	ND(<1)	>133%
31	32	ND(<1)	>188%
37	15	ND(<1)	>175%
8	22	300	173%
14	ND(<0.1)	200	200%
15	ND(<0.1)	30	200%
17	2.9	ND(<0.1)	>187%
29	ND(<0.1)	0.3	>100%
8	ND(<0.1)	50	>199%
42	0.4	0.1	120%

Parameter	EPA	Company	Percent Difference
15	522	200	89%
17	ND(<1)	7	>150%
29	7.5	1.7	126%
30	16	4.1	118%
36	5.5	2	85%
8	ND(<1)	4	>120%
15	ND(<1)	40	>190%
30	7	0.06	168%
8	ND(<1)	3.6	>113%
15	ND(<1)	5	>133%
29	29	3.4	158%
37	ND(<1)	5	>133%
39	ND(<1)	3.2	>105%
42	33	8	122%
45	ND(<1)	2.5	> 86%
24	1.8	4.4	84%
30	10	2.9	110%
35	6.5	0.6	84%
37	ND(<1)	2.2	> 75%
37	ND(<1)	10	>164%

TABLE B-6. TRACE ELEMENTS (µg/ℓ) - LABORATORY COMPARISONS

Comparison Lab 1 vs. Lab 2	Radian vs. EPA Labs Refineries 2, 7, 9		Radian vs. Company Refineries 2, 7, 9		EPA Labs vs. Company Refineries 2, 7, 9, 11, 16	
	Number	Percent	Number	Percent	Number	Percent
Inconclusive	63	52%	12	19%	21	33%
Second Lab High:	6	4%	5	8%	25	39%
Not Quantifiable	--	--	--	--	7	11%
≤75% High	3	2%	1	2%	8	12%
>75% High	3	2%	4	6%	10	16%
Second Lab Low:	52	44%	47	73%	18	28%
Not Quantifiable	20	17%	8	12%	1	2%
≤75% Low	15	13%	17	27%	8	12%
>75% Low	17	14%	22	34%	9	14%
Total Comparisons	121	100%	64	100%	64	100%

COMPARISONS WITH DIFFERENCES GREATER THAN 75%

Parameter	Radian	EPA	Percent Difference
2	1300	7	198%
3	35	ND(<5)	>150%
7	190	ND(<15)	>171%
12	4.1	ND(<1)	>122%
3	130	11	169%
7	54	ND(<15)	>113%
3	65	ND(<5)	>171%
2	79	ND(<5)	>176%
3	62	7	159%
2	94	ND(<5)	>180%
3	52	ND(<5)	>182%
10	74	ND(<20)	>115%
2	11	40	114%
3	68	ND(<5)	>173%
2	800	72	167%
3	26	ND(<5)	>135%
6	68	360	136%
7	33	ND(<15)	> 75%
3	16	ND(<5)	>105%
6	68	370	138%

Parameter	Radian	Company	Percent Difference
1	23	10	79%
3	65	26	86%
11	9	1	160%
1	48	12	120%
3	62	6	165%
4	8	26	106%
8	4.9	ND(<2)	> 84%
1	27	10	92%
3	52	3	178%
4	3	46	176%
2	11	ND(<1)	>167%
3	68	ND(<1)	>194%
9	18	ND(<1)	>179%
10	15	ND(<1)	>175%
3	26	7	115%
4	4	ND(<1)	>120%
6	68	240	112%
7	33	1	188%
8	3.6	27	153%
9	23	6	152%
11	2.3	ND(<1)	> 79%
6	68	190	95%
7	9.5	ND(<1)	>162%
8	3.6	18	133%
9	16	2	156%
10	15	ND(<1)	>175%

Parameter	EPA	Company	Percent Difference
2	1400	587	82%
2	ND(<5)	26	>135%
1	30	12	86%
2	ND(<5)	50	>164%
1	25	10	86%
2	ND(<5)	50	>164%
4	ND(<15)	46	>102%
2	40	ND(<1)	>190%
2	72	690	162%
3	ND(<5)	12	> 82%
1	45	10	>127%
2	5	2	86%
3	280	ND(<20)	>173%
9	ND(<20)	50	> 86%
12	3	ND(<1)	>100%
1	120	30	120%
2	73	230	104%
9	ND(<20)	70	>111%
2	54	120	76%

The other subclassifications quantify how much higher (or lower) a laboratory reports their analysis. The percent difference between the two reported values is computed as follows:

$$\text{Percent Difference} = \frac{|\text{Lab A Analysis} - \text{Lab B Analysis}|}{(\text{Lab A Analysis} + \text{Lab B Analysis})/2} \times 100$$

The percent difference is classified as either greater than 75% or less than or equal to 75%. Comparisons resulting in a difference of greater than 75% are tabulated at the bottom of the appropriate table.

A number of important results are summarized in these comparison tables. First, although data with both laboratories reporting ND(<X) was excluded from the comparisons, a large percentage of the comparisons are still inconclusive. For the volatile organics, 62% of the comparisons of the EPA laboratories with the other laboratories were inconclusive. Twenty-three percent of the comparisons were inconclusive when comparing the company laboratories with Radian laboratories. For both the liquid/liquid extractables and the trace elements, 39% of all comparisons were inconclusive. Most of these inconclusive comparisons were due to one of the laboratories reporting the result as ND(<X) with relatively large values of "X". For instance, if Lab A reports ND(<100), the comparison is inconclusive for any quantified result reported by Lab B less than 100.

Another important result from these summary comparisons is the magnitude of the differences when the comparisons could be quantified. In general there are more comparisons with differences greater than 75% than there are comparisons with differences less than 75%. The following table summarizes the percent differences from the comparison tables for all laboratories where the comparisons were conclusive:

Comparisons Which Were Conclusive	Volatile Organics		Liquid/Liquid Extractable Organics		Trace Elements	
	Number	Percent	Number	Percent	Number	Percent
Difference Not Quantifiable	24	28%	15	14%	36	24%
Difference ≤75%	15	17%	17	16%	52	34%
Difference >75%	48	55%	73	70%	65	42%
Total	87	100%	105	100%	153	100%

The high percentage of comparisons with differences greater than 75% is attributable to many effects including repeatability of the test methods, interferences from contamination, variability in recoveries for the extraction techniques, as well as differences between laboratories.

Some consistent differences between laboratories in one direction (high or low) are noted in Tables B-4 through B-6. For the volatile organics the Radian results tend to be higher than the company results (Radian is lower on 20% of comparisons and higher on 47%). Many of the high results are due to comparisons in which Radian reported a quantitative value and the company reported ND(<X).

For the liquid/liquid extractable organics, Radian tends to report higher values than the EPA laboratories (Radian is higher 47% of the time and lower 22% of the time). As before, this is often due to the EPA laboratories reporting a ND(<X) value while Radian reported a quantitative value greater than "X". In the trace element comparisons, Radian tends to be higher than both the EPA laboratories and the company laboratories.

The large differences (>75%) need to be kept in perspective. Often the sample concentrations are near the detection

limits of the test procedures where relatively large quantitative differences would be expected; for example, 75% of a 4 ppb concentration is only a difference of 3 ppb.

5.2 Graphical Comparisons

A further procedure was used to enable a graphical comparison of laboratory results. Often in statistical analysis and data bases, data reported as ND(<X) or D(<X) are quantified as "X/2" for purposes of statistical analysis of the data. The general assumption is uniformity or symmetry of concentrations between zero and the detection limit. The occurrence of relatively high detection limits for some parameters (10, 20, 50, & 100 ppb) and the high degree of skewness (relatively few high reported values) of the reported data makes this assumption questionable for this data. The following procedures were used to quantify the data from this study:

- Data reported as G (X), i.e., greater than "X" is quantified as X.
- Data reported as D (<X) and ND (<X) is handled as follows:
  - If X is less than 4.0, the data is quantified as X/2, i.e., the midpoint between 0.0 and the detection limit.
  - If X is greater than or equal to 4.0, the data is quantified as $\sqrt{X}$, i.e., the square root of the detection limit. This transformation is based on the assumption that the data is log-normally distributed. Taking the square

roots on an arithmetic scale is equivalent to taking the midpoint on a log-scale and then transforming back to the arithmetic scale.

Some examples to clarify this procedure follow:

Data Reported As (ppb):	Data Quantified As (ppb):
G(10)	10.0
ND(<1) or D(<1)	0.5
ND(<2) or D(<2)	1.0
ND(<4) or D(<4)	2.0
ND(<5) or D(<5)	2.2
ND(<10) or D(<10)	3.2
ND(<50) or D(<50)	7.1
ND(<100) or D(<100)	10.0

This procedure is simply a device to display laboratory comparisons on a consistent basis.

Figures B-1 through B-10 show graphical comparisons of the various laboratories including data that was quantified using the above procedures. The solid line represents perfect agreement between the laboratories being compared. The distance from this line measures the difference between the two laboratories (a logarithmic scale is used).

The visual evaluation of these graphs may not always completely agree with the comparisons in Tables B-4 through B-6. The differences between the comparisons are due to the following reasons:

- The graphical comparisons are made only when the same type of sample (composite

FIGURE B-1.

COMPARISON OF VOLATILE ORGANICS ANALYSIS
REFINERY 2
RADIAN VS. EPA RESULTS

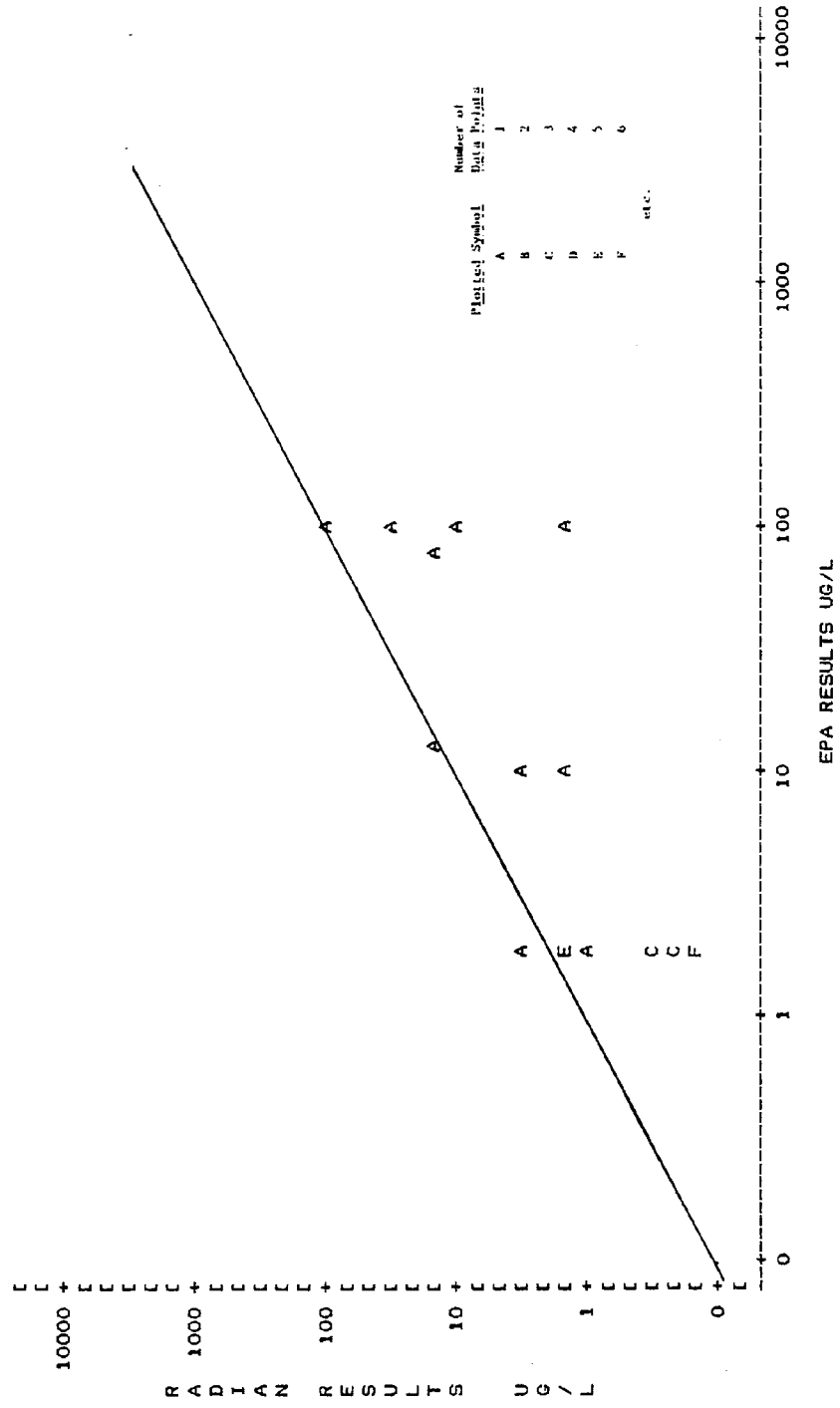


FIGURE B-2.

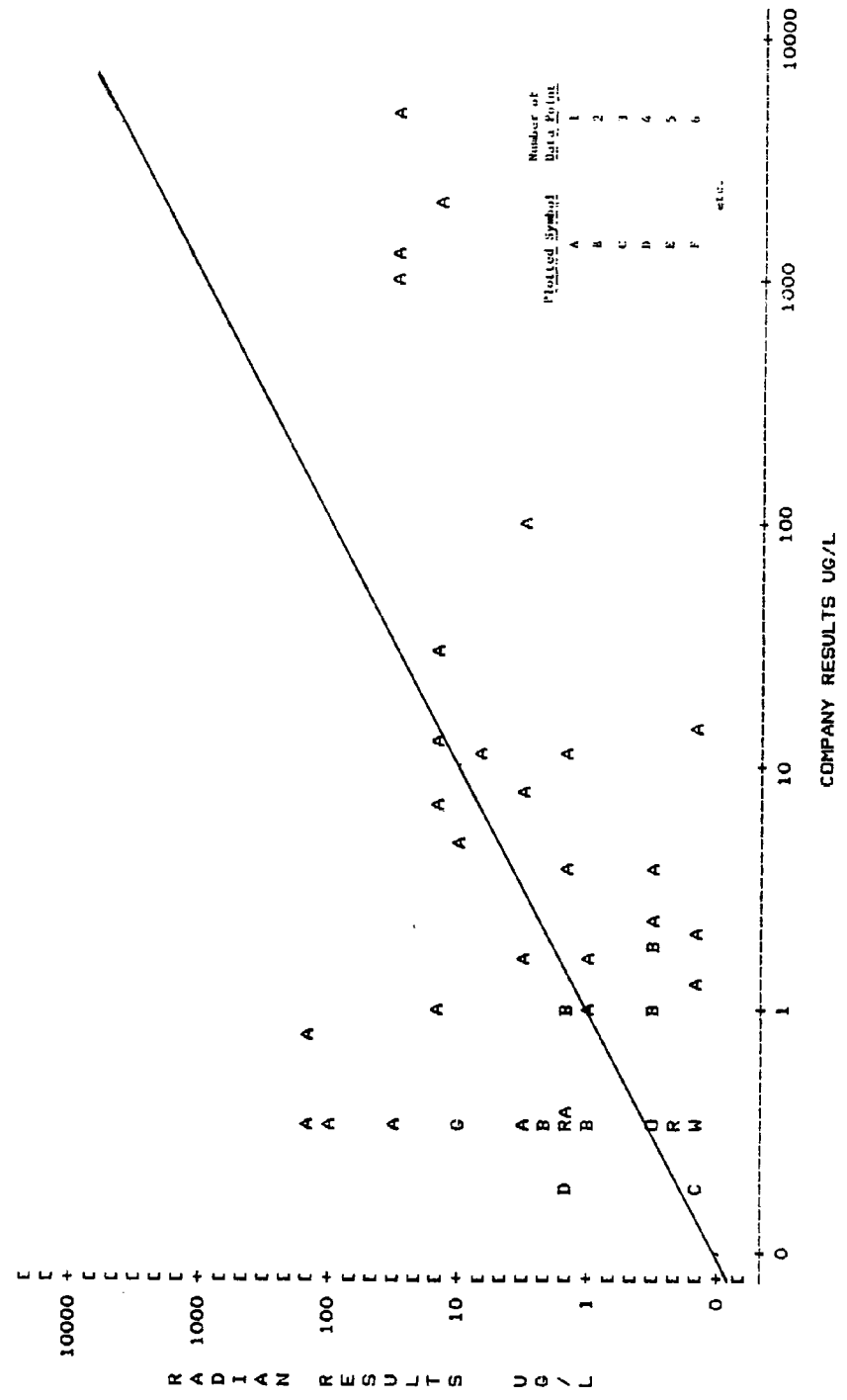


FIGURE B-3.

COMPARISON OF VOLATILE ORGANICS ANALYSIS
REFINERY 2
EPA VS. COMPANY RESULTS

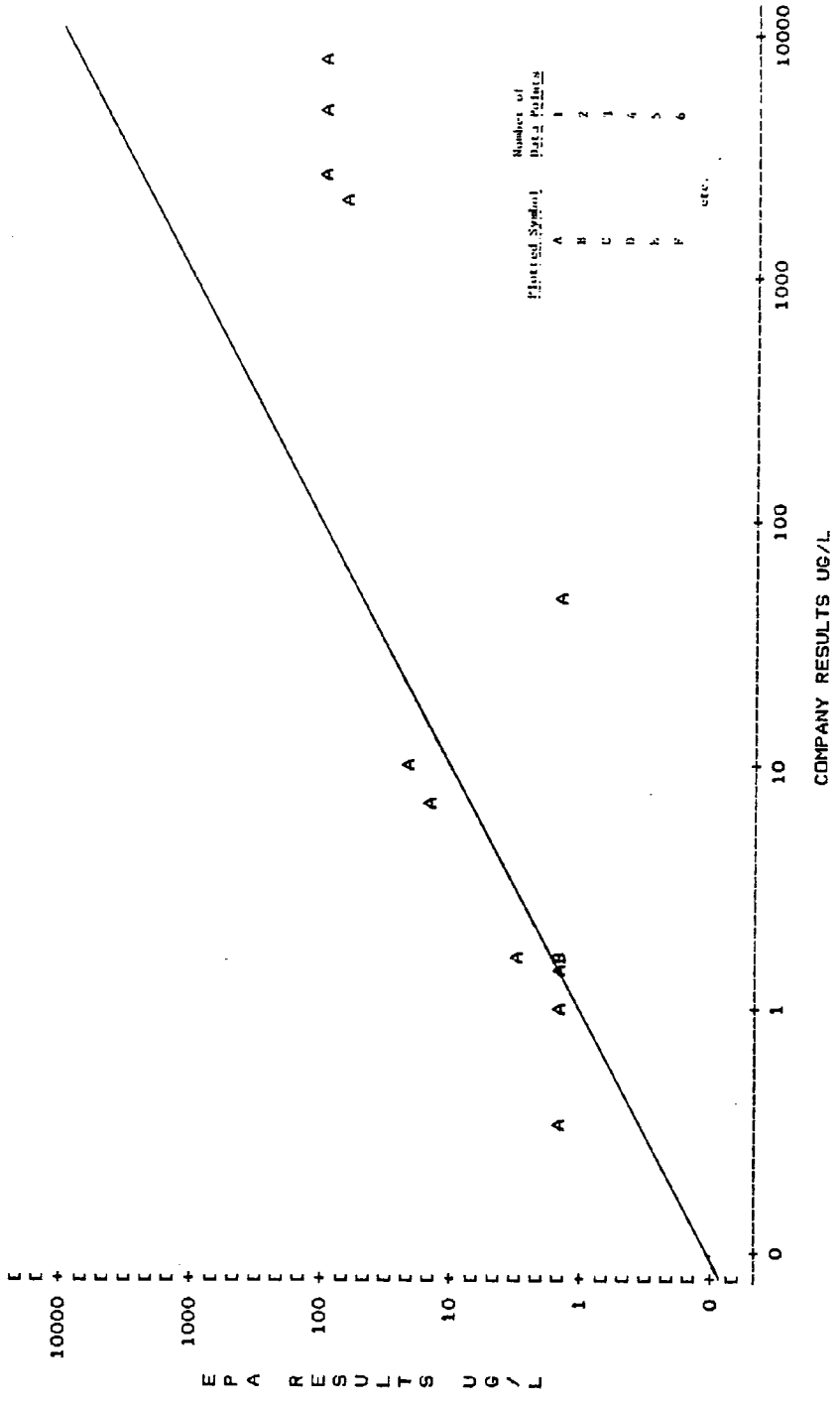


FIGURE B-4.

COMPARISON OF LIQUID -LIQUID EXTRACTABLE ORGANICS ANALYSIS
REFINERY 2
RADIAN VS. EPA RESULTS

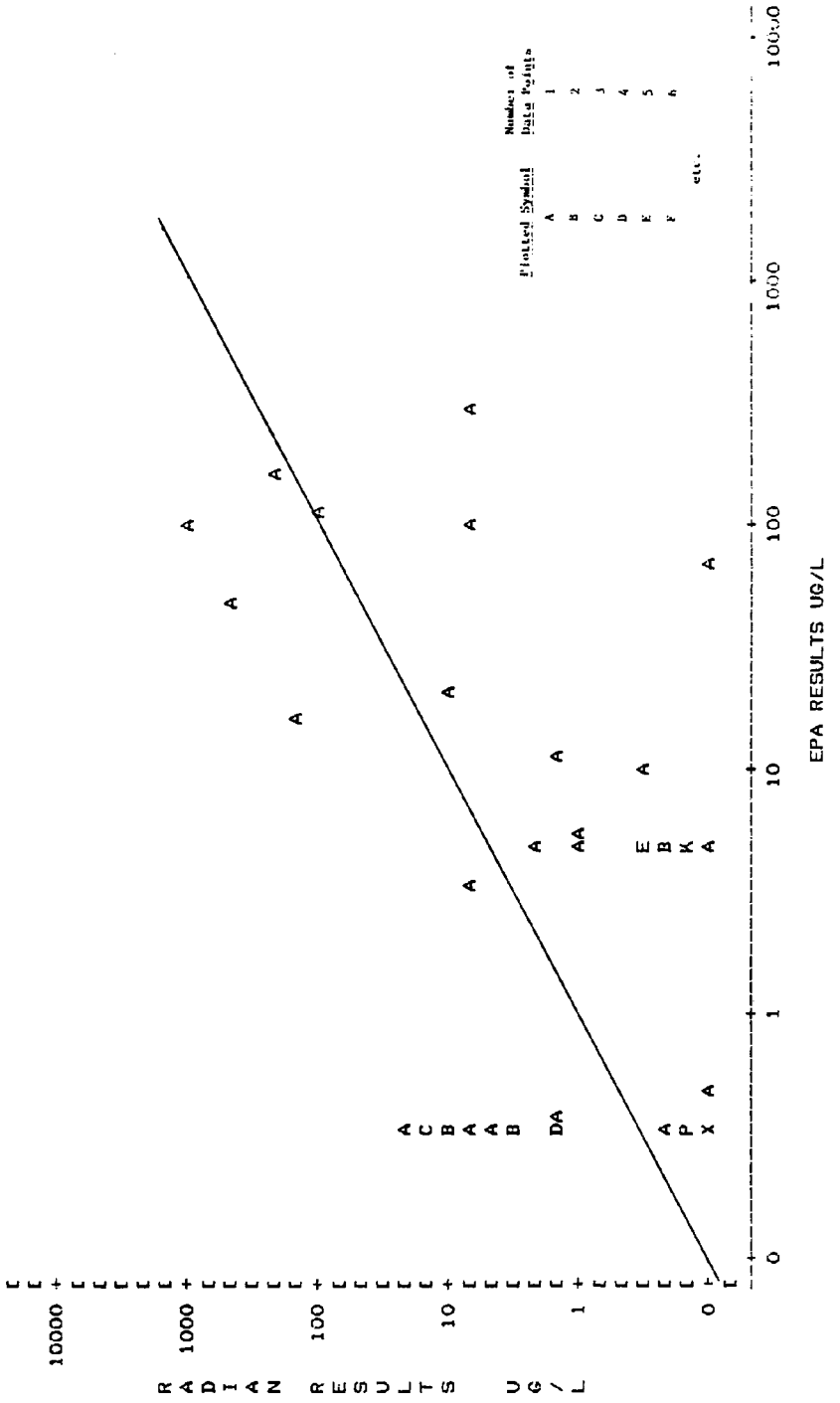


FIGURE B-5.

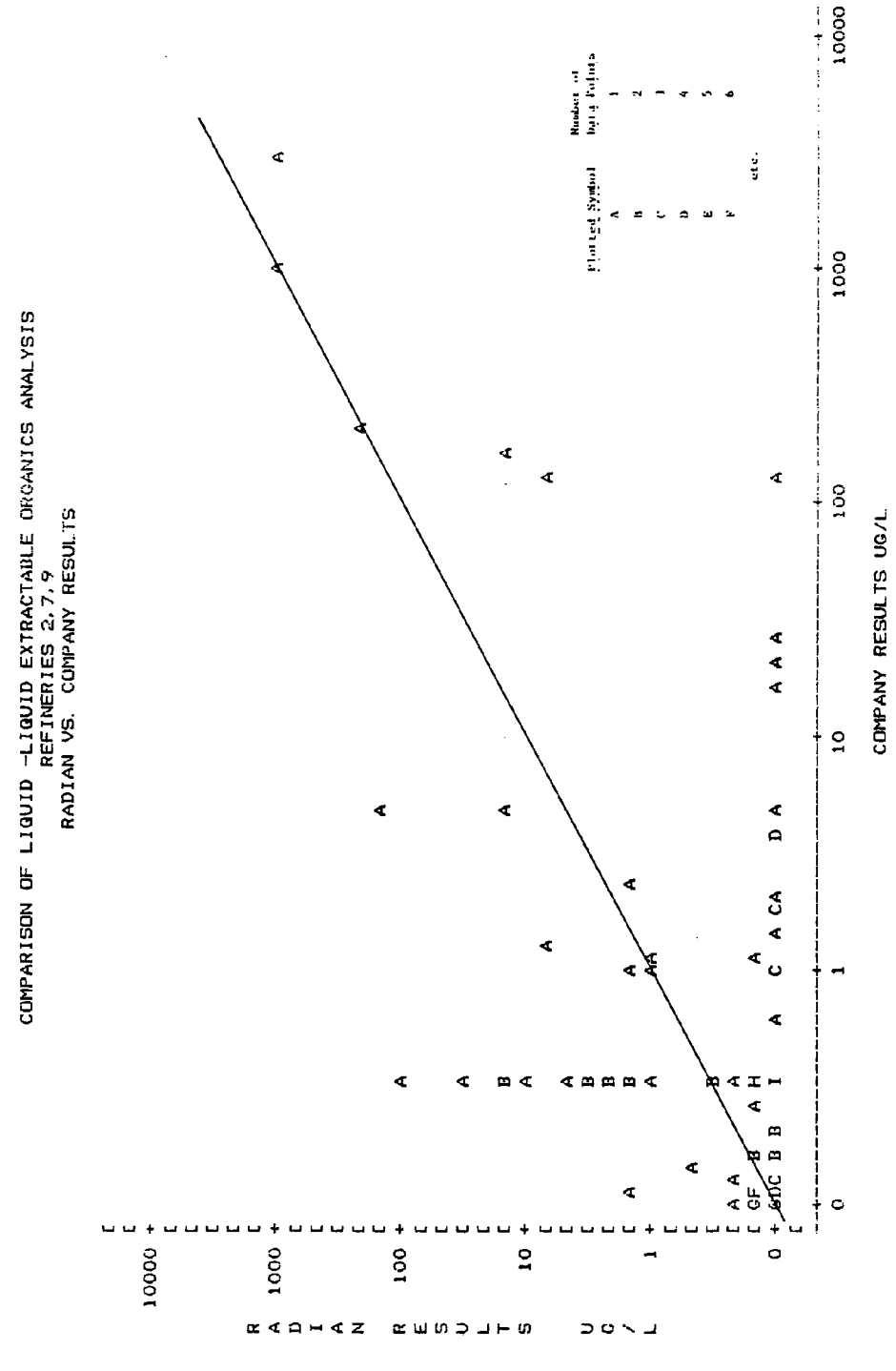


FIGURE B-6.

COMPARISON OF LIQUID -LIQUID EXTRACTABLE ORGANICS ANALYSIS
REFINERIES 2,6
EPA VS. COMPANY RESULTS

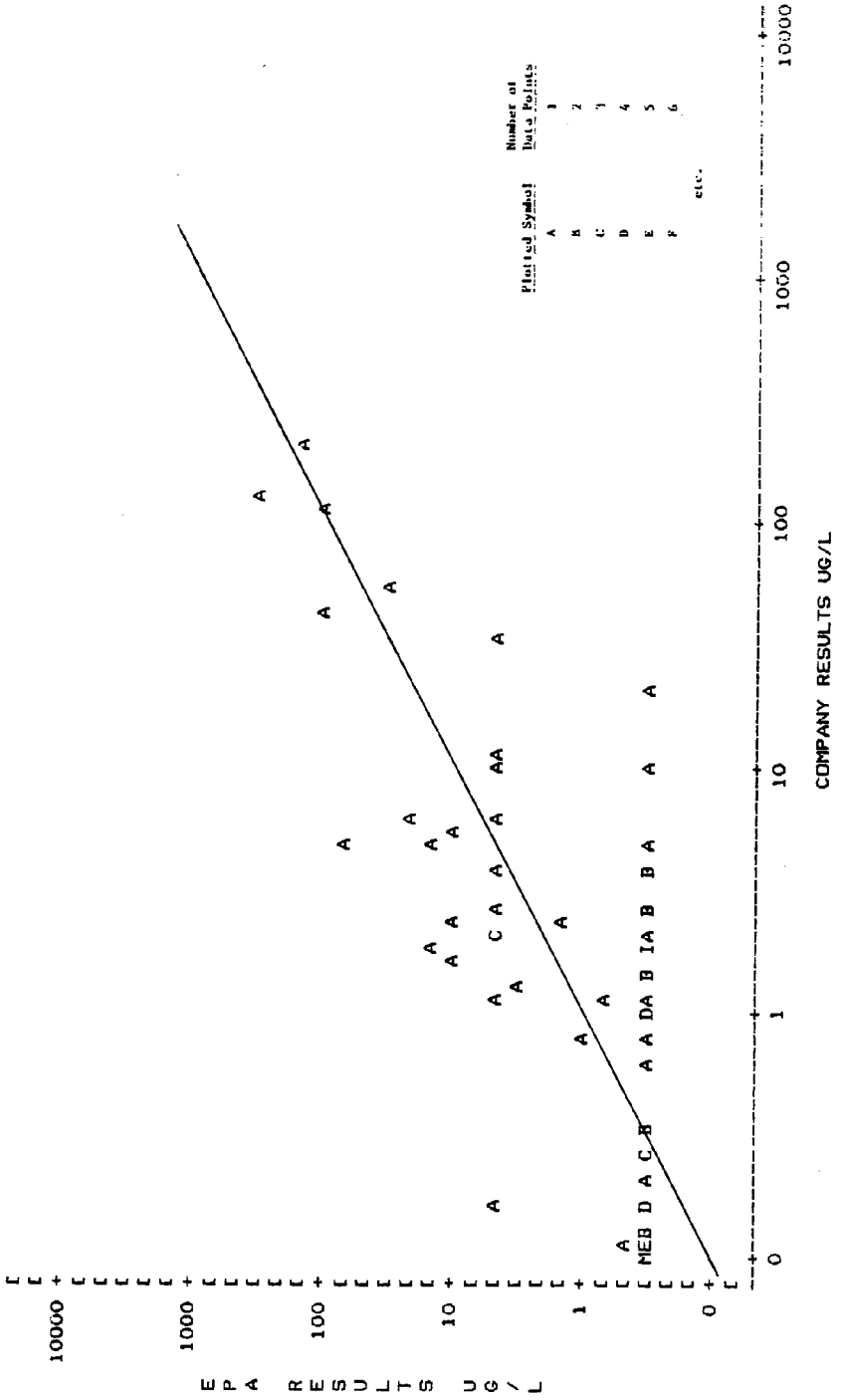


FIGURE B-7.

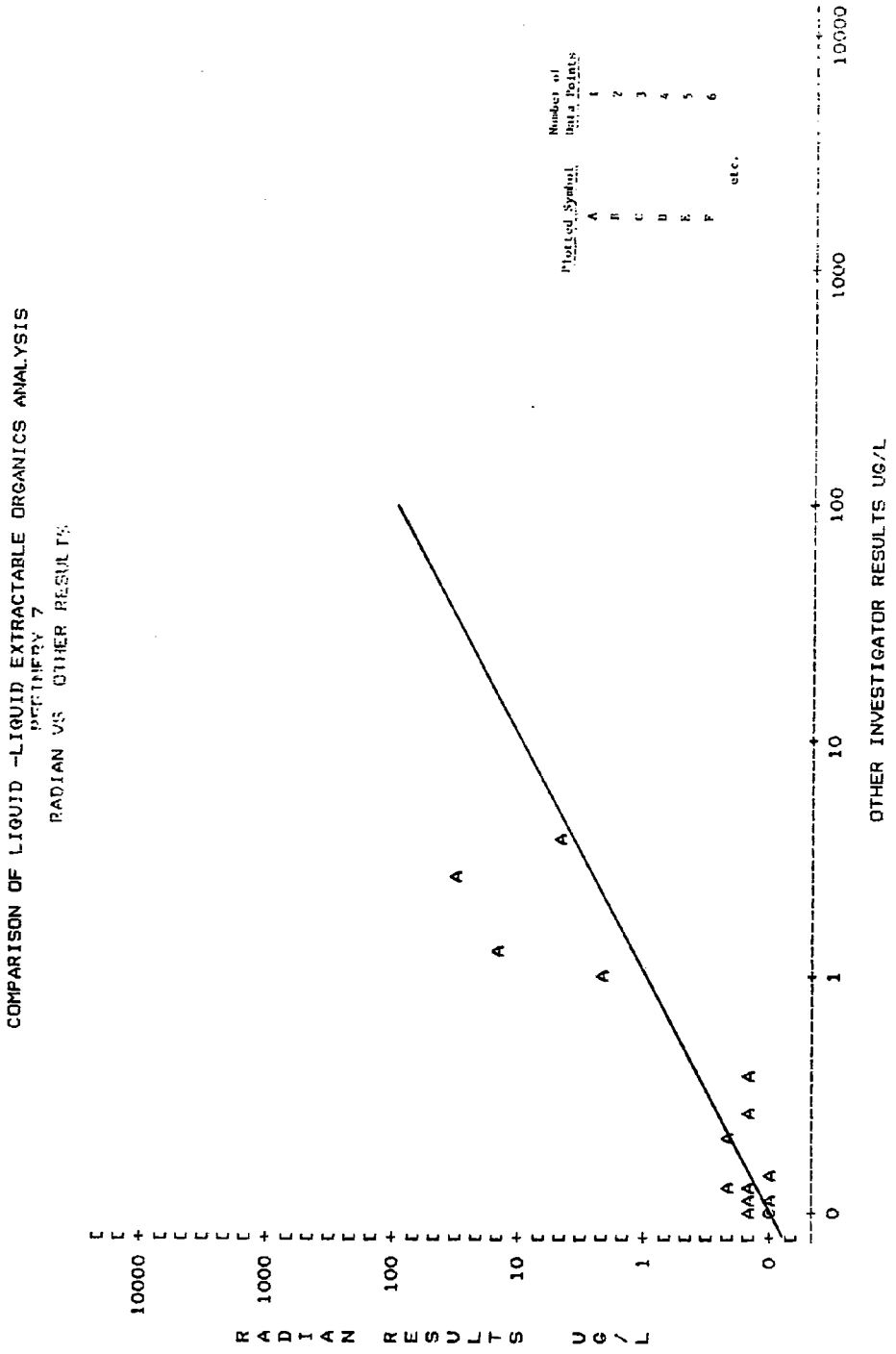


FIGURE B-8.

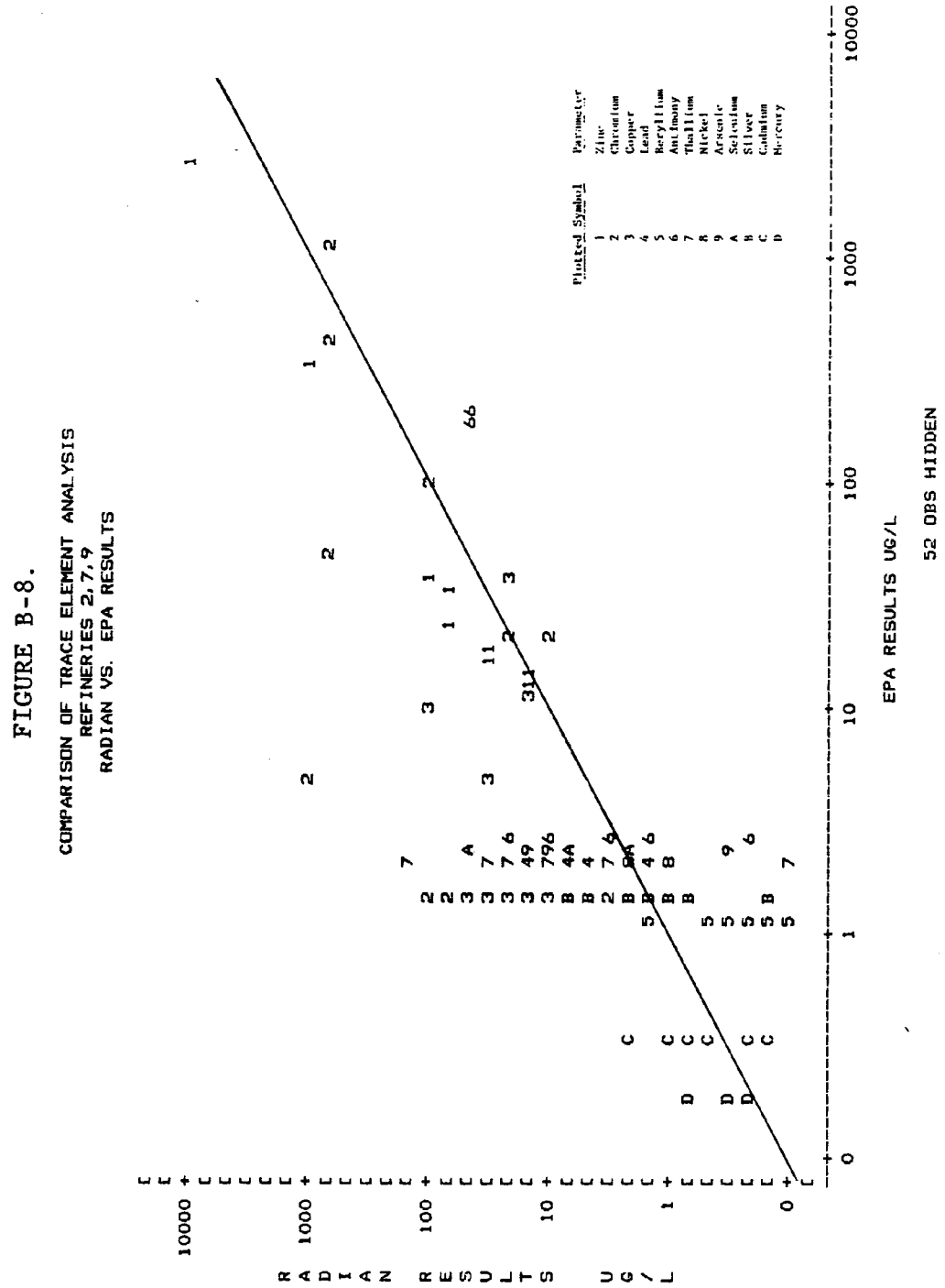


FIGURE B-9.

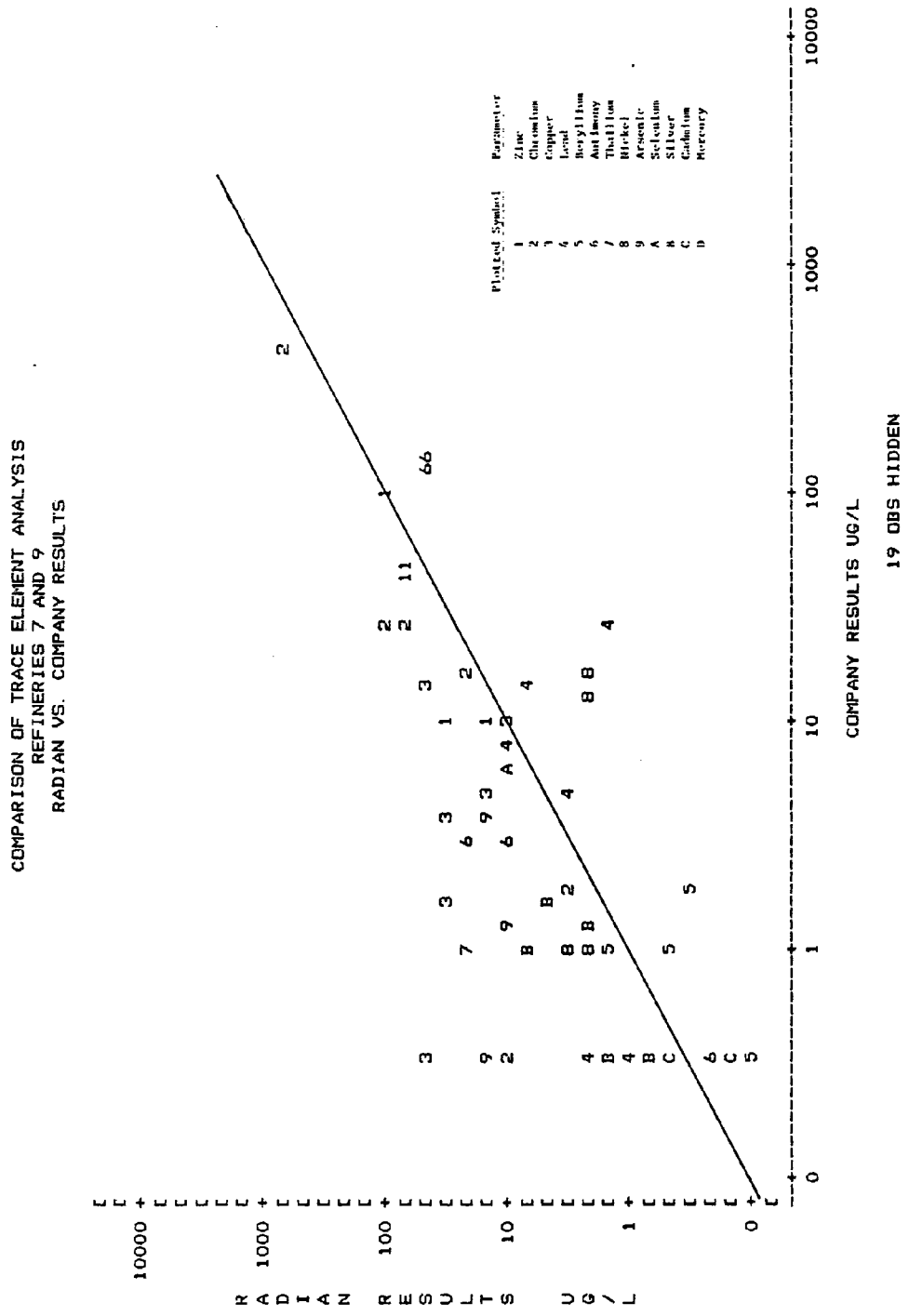
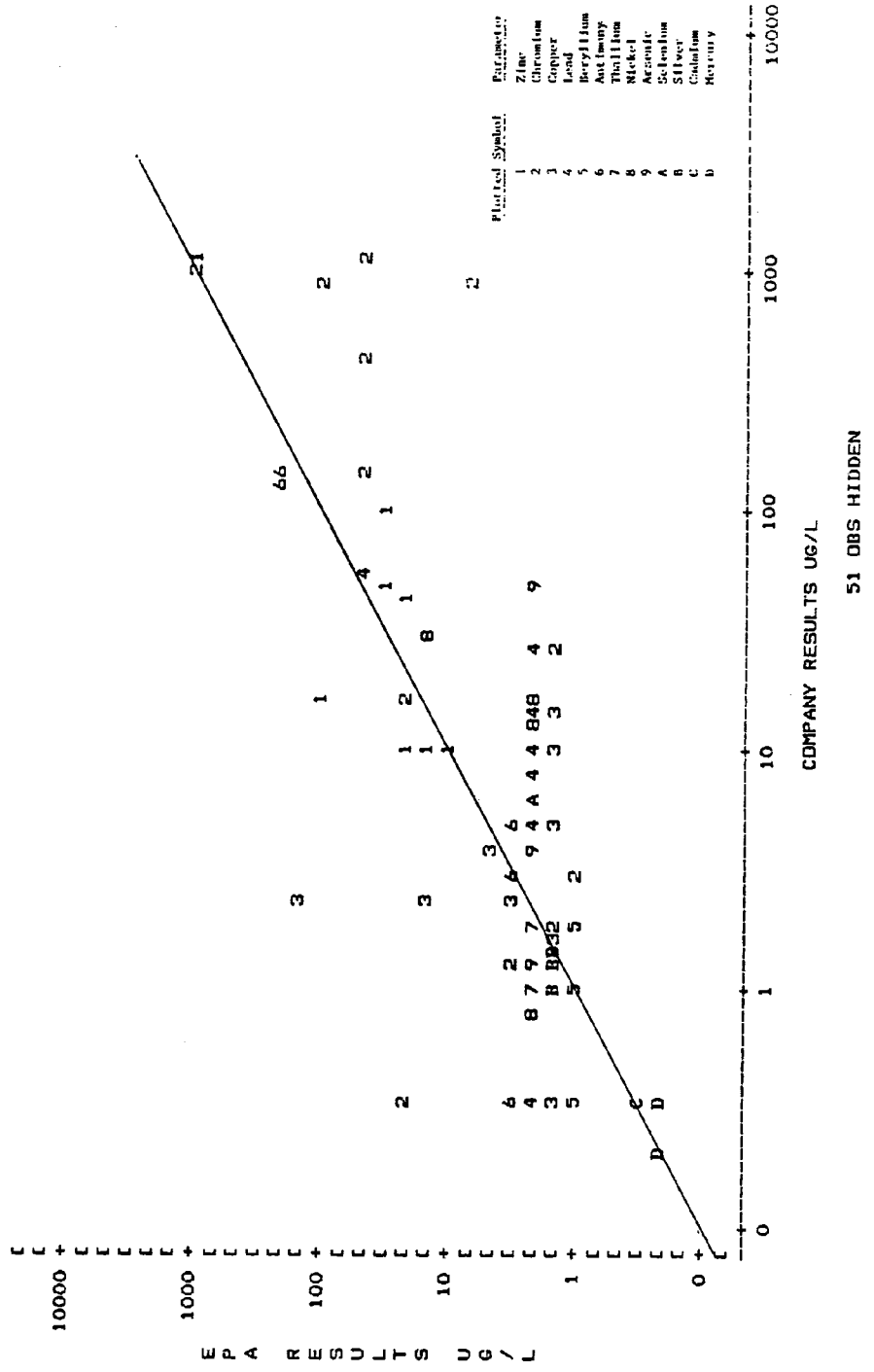


FIGURE B-10.



vs. individual day) was analyzed by both laboratories. For example, Day 1 samples were only compared with other Day 1 samples and Day 6 samples only with other Day 6 samples. This eliminates variability due to different sample types from the comparisons.

- There is additional data on the graphs which were reported as "inconclusive" in the tables because the "ND" and "D" reported data were assigned values as described previously.

When Figures B-1 through B-10 are compared with the appropriate sections of Tables B-4, B-5, and B-6, the conclusions generally agree. The graphical comparisons add a new dimension in that many of the inconclusive results in the tables can be evaluated on the graphs. This additional information allows one to compare differences in laboratories due to different detection limits or different sensitivities in their test procedures.

The graphical procedures also allow a comparison of laboratories for different concentration levels. For example, Table B-7 comparing EPA and company laboratory trace element results shows no consistent biases between the laboratories. However, Figure B-10 shows that the EPA results tend to be higher at concentrations less than 5 ppb while the company results tend to be higher for concentrations greater than 50 ppb. Figure B-8 shows that Radian results tend to be higher than EPA results at all concentration levels (in agreement with Table B-6).

The effect of detection limits becomes apparent whenever the plotted values on the graphs tend to form straight lines. For instance, in Figure B-5, which compares Radian and company results for the liquid/liquid extractable organics, both vertical and horizontal "lines" are formed by the plotted points. The vertical line is due to the companies reporting data at ND(<1) while Radian reported concentrations ranging from ND(<0.1) to 100 ppb for the same samples. The horizontal line is due to Radian reporting results at ND(<0.1) for which the companies reported results ranging from ND(<0.01) to 200 ppb.