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TECHNOLOGY EVALUATION REPORT:

# BIOTROL SOIL WASHING SYSTEM FOR TREATMENT OF A WOOD PRESERVING SITE

Volume I

by

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## NOTICE

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## FOREWORD

The Superfund Innovative Technology Evaluation (SITE) program was authorized in the 1986 Superfund amendments. The program is a joint effort between EPA's Office of Research and Development and Office of Solid Waste and Emergency Response. The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to implement new cleanup standards which require greater reliance on permanent remedies. This is accomplished through technology demonstrations which are designed to provide engineering and cost data on selected technologies.

This project consists of an analysis of one configuration of BioTrol, Inc.'s proprietary soil washing system. The demonstration took place at the MacGillis & Gibbs Superfund site in New Brighton, Minnesota, a wood treatment facility operating since approximately 1920. The demonstration effort was directed at obtaining information on the performance and cost of the process sequence for use in assessments at other sites. Documentation for the project consists of this Technology Evaluation Report and an Applications Analysis Report. The Technology Evaluation Report provides a detailed analysis of the data acquired during the demonstration; discusses the technical aspects of the technology; and describes the field activities and laboratory results. The Applications Analysis Report summarizes the results of the demonstration and looks more broadly at the applicability of the technology to other sites and the criteria (e.g., site and waste characteristics, economics, etc.) that would need to be addressed.

For further information, please contact the Superfund Technology Demonstration Division at the Risk Reduction Engineering Laboratory.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

## ABSTRACT

The SITE Program demonstration of one configuration of the BioTrol Soil Washing System (BSWS) was conducted to obtain reliable performance and cost data that can be used to evaluate the potential applicability of the technology as a remediation alternative for sites contaminated with hazardous wastes. The BSWS treatment train used in this study consists of three technologies: a soil washer; an aqueous treatment system; and a slurry bio-reactor. The demonstration was carried out at the MacGillis & Gibbs Superfund site in New Brighton, MN.

Contaminated soils were treated by the soil washer (SW) using a multi-stage countercurrent attrition/classification and flotation system to separate heavily contaminated fine soil particles from the bulk soil. The SW operates on the principle that most of the contaminants are associated with the fine size fraction of the bulk soil. The heavily contaminated fine soil particles are treated in a Slurry Bio-Reactor (SBR), a cascading aerated reactor system using biological degradation. Contaminated process water from the SW is biodegraded in the BioTrol Aqueous Treatment System (BATS) using an aerated, fixed-film reactor.

This report analyzes the results from this SITE demonstration. It includes discussion of the operation of the three separate treatment technologies (SW, SBR, and BATS) evaluated in this test and provides flow diagrams, a summary of the sampling and analytical programs, an economic analysis, and a quality assurance/quality control evaluation of the data.

Conclusions were reached concerning the technology's suitability for use in remediations involving both similar and different materials at other sites. The conclusions from the test results and from other available data are:

- The Soil Washer (SW) can achieve removal efficiencies up to 89% for pentachlorophenol (penta) and polynuclear aromatic hydrocarbons (PAHs), based on the reduction in penta mass from the Feed Soil to the Washed Soil output fraction. As a result of the segregation in the SW, the Washed Soil constitutes about 83% of the output stream solids.

- Specifically, the two Feed Soils, with weighted average penta concentrations of 130 mg/Kg and 680 mg/Kg penta, produced Washed Soil streams with weighted average penta concentrations of 14 mg/Kg and 87 mg/Kg. Total PAHs decreased from 247 mg/Kg and 404.1 mg/Kg in the same two Feed Soils to 42 mg/Kg and 48 mg/Kg in the Washed Soils.

- A small quantity of a fine particle cake (~7% of output solids) retaining a major portion of the penta and PAH contamination (about 30% of the total output) is also obtained. With the MacGillis and Gibbs soils, two additional fractions containing significant amounts of penta and PAHs were also obtained.

- The Slurry Bio-reactor (SBR) appears to be capable of achieving pentachlorophenol removal of >90% and PAH removals in the 70-90+% range; however, the unit did not reach steady state operation and optimum performance was not reached.

- The BioTrol Aqueous Treatment System (BATS) can achieve up to 94% degradation of pentachlorophenol in process water from the SW. Removal of PAHs could not be determined because influent concentrations were below detection limits.

- The estimated cost to install and operate an integrated pilot-scale system (SW, BATS, SBR), based on a 0.25-0.50 ton/hr Soil Washer operating for two weeks to assess applicability for remediation is $745,000. For a full-scale system the total cost (capital plus operating) to clean up 30,000 $yd^3$, such as at the MacGillis and Gibbs site, is estimated at about $168/ton, based on a 20 ton/hr Soil Washer, three 100 gpm BATS units, and a 23 gpm SBR. This figure does include incineration of contaminated fine and coarse oversize material, which constributes about 75% to the total cost. Costs for a full-scale, operating system were not available at the time this report was prepared.

VOLUME I*
TABLE OF CONTENTS


| | PAGE |
|---|---|
| FOREWORD | iii |
| ABSTRACT | iv |
| TABLE OF CONTENTS | vi |
| LIST OF FIGURES | x |
| LIST OF TABLES | xii |
| TABLE OF ABBREVIATIONS AND SYMBOLS | xv |
| CONVERSION FACTORS | xvii |
| ACKNOWLEDGEMENTS | xviii |
| SECTION 1. INTRODUCTION | 1 |
| 1.1 THE SITE PROGRAM | 1 |
| 1.2 OBJECTIVES OF THE DEMONSTRATION | 2 |
| 1.3 SITE DESCRIPTION | 2 |
| 1.4 DESCRIPTION OF OPERATIONS | 4 |
| 1.5 PROJECT ORGANIZATION | 6 |
| SECTION 2. EXECUTIVE SUMMARY | 8 |
| 2.1 SITE DEMONSTRATION | 8 |
| 2.2 SUMMARY OF RESULTS | 9 |
| 2.2.1 Soil Washer | 9 |
| 2.2.2 BioTrol Aqueous Treatment System | 10 |
| 2.2.3 Slurry Bio-Reactor | 10 |
| 2.3 CONCLUSIONS | 10 |
| 2.3.1 Soil Washer | 10 |
| 2.3.2 BioTrol Aqueous Treatment System | 11 |
| 2.3.3 Slurry Bio-Reactor | 11 |
| 2.3.4 Costs | 12 |
| SECTION 3. PROCESS DESCRIPTION | 13 |
| 3.1 PRETREATMENT AND PROCESSING REQUIREMENTS | 13 |
| 3.1.1 Soil Excavation and Preparation | 13 |
| 3.1.2 Process Water | 13 |
| 3.1.3 Slurry for SBR | 13 |


* Volume II is published in two separate documents - Part "A" and Part "B"; it contains operating data and analytical results.

TABLE OF CONTENTS (CONT'D)


| | | PAGE |
|---|---|---|
| 3.2 | PROCESS DESCRIPTION | 14 |
| | 3.2.1 Introduction | 14 |
| | 3.2.2 Soil Washer | 14 |
| | 3.2.3 BioTrol Aqueous Treatment System | 16 |
| | 3.2.4 Slurry Bio-Reactor | 20 |
| 3.3 | ANCILLARY POLLUTION CONTROL EQUIPMENT | 23 |
| 3.4 | WASTE REMOVAL AND SITE CLOSURE | 23 |
| SECTION 4. | THE BIOTROL FIELD DEMONSTRATION | 24 |
| 4.1 | BACKGROUND | 24 |
| | 4.1.1 Technology Description | 24 |
| | 4.1.2 Site Description | 24 |
| | 4.1.3 Demonstration Test Plan | 26 |
| 4.2 | DEMONSTRATION PROCEDURES | 26 |
| | 4.2.1 Site Preparation | 26 |
| | 4.2.2 Field Operations | 27 |
| | 4.2.2.1 Soil Washer Demonstration | 27 |
| | 4.2.2.2 BioTrol Aqueous Treatment System Test | 29 |
| | 4.2.2.3 Slurry Bio-Reactor Test | 28 |
| | 4.2.3 Field Measurements | 28 |
| | 4.2.3.1 Soil Washer | 28 |
| | 4.2.3.2 BioTrol Aqueous Treatment System | 28 |
| | 4.2.3.3 Slurry Bio-Reactor | 28 |
| | 4.2.4 Sampling and Analysis | 32 |
| | 4.2.4.1 Predemonstration Sampling and Analysis | 32 |
| | 4.2.4.2 Demonstration Sampling and Analysis | 34 |
| | 4.2.4.3 Post Demonstration Sampling and Analysis-- | 35 |
| | 4.2.5 Health and Safety Protocols | 38 |
| 4.3 | MATERIAL CHARACTERIZATION | 38 |
| | 4.3.1 Feed Soils | 38 |
| | 4.3.2 Soil Washer Output Streams | 44 |
| 4.4 | PILOT SYSTEM PERFORMANCE RESULTS | 52 |
| | 4.4.1 Introduction | 52 |
| | 4.4.2 Soil Washer Performance | 52 |
| | 4.4.2.1 As-is Material Balance | 54 |
| | 4.4.2.2 Dry Solids Material Balance | 58 |
| | 4.4.2.3 Penta Distribution - Low Penta SW Test | 58 |
| | 4.4.2.4 Penta Distribution - High Penta SW Test | 64 |
| | 4.4.2.5 PAH Distribution | 67 |
| | 4.4.2.6 Total Organic Carbon and Total Recoverable Petroleum Hydrocarbons | 77 |
| | 4.4.2.7 Metals Behavior | 77 |

TABLE OF CONTENTS (CONT'D)


PAGE

4.4.2.8 Flow Rate Stability ..... 80
Low Penta SW Material Flow Rates
High Penta SW Material Flow Rates
Feed Soil Flow Rate Effect on Organics Removal
4.4.3 BioTrol Aqueous Treatment System Performance ..... 92
4.4.3.1 Critical Analyses ..... 92
4.4.3.2 Other Analyses ..... 99
4.4.3.3 System Parameters ..... 111
4.4.4 Slurry Bio-Reactor Performance ..... 111
4.4.4.1 Critical Analyses ..... 111
4.4.4.2 Other Analyses ..... 152
4.4.4.3 System Parameters ..... 161
4.4.5 Dioxins ..... 169
4.4.5.1 Introduction ..... 169
4.4.5.2 CDD/CDFs in Soil Washer Streams ..... 169
4.4.5.3 CDD/CDFs in the BATS ..... 169
4.4.5.4 CDDs/CDFs in the Slurry Bio-Reactor ..... 173

4.5 FACTORS AFFECTING THE DEMONSTRATION ..... 176
4.5.1 Unit Operating Problems - Soil Washer..... 176
4.5.2 BioTrol Aqueous Treatment System - Problems ..... 176
4.5.3 Slurry Bio-Reactor - Problems ..... 177

4.6 POTENTIAL OVERALL BSWS PERFORMANCE..... 177

SECTION 5. ECONOMIC ANALYSIS ..... 179

5.1 INTRODUCTION ..... 179

5.2 BASIS OF ECONOMIC ANALYSIS ..... 179

SECTION 6. QUALITY ASSURANCE/QUALITY CONTROL ..... 183

6.1 INTRODUCTION ..... 183

6.2 CONCLUSIONS AND LIMITATIONS OF DATA ..... 184

6.3 PROCEDURES DEFINING DATA QUALITY ..... 185
6.3.1 Precision ..... 185
6.3.2 Accuracy ..... 186
6.3.3 Completeness ..... 186
6.3.4 Comparability ..... 186
6.3.5 Representativeness ..... 187

6.4 ANALYTICAL QUALITY CONTROL ..... 187
6.4.1 Soil Pile Analyses ..... 187
6.4.2 Soil Washer Analyses ..... 199
6.4.3 Aqueous Treatment System Analyses ..... 210

TABLE OF CONTENTS (CONT'D)

PAGE

6.4.4 Slurry Bioreactor ..... 218
6.4.5 Blank Results ..... 229

6.5 SPECIAL STUDIES ..... 229

6.6 AUDITS AND RESULTING QAPjP DEVIATIONS ..... 243
6.6.1 Biotrol Soils Audit ..... 243
6.6.2 Laboratory Audit at 1st Subcontractor Laboratory and Field Audit of Slurry Bioreactor ..... 245
6.6.3 Technical Systems Review (TSR) at Second Subcontractor Laboratory ..... 245
6.6.4 Follow-up Audit of 2nd Subcontracting Laboratory ..... 250
6.6.5 Audit of Soil Sieving Procedure for BioTrol Project .... 251

SECTION 7. BIBLIOGRAPHY ..... 254

## LIST OF FIGURES


| | | PAGE |
|---|---|---|
| 1-1. | SITE DEMONSTRATION LOCATION AT MACGILLS & GIBBS | 3 |
| 1-2. | MACGILLIS AND GIBBS/BIOTROL SITE MAP | 5 |
| 1-3. | PROJECT ORGANIZATION | 7 |
| 3-1. | FLOW DIAGRAM OF SOIL WASHER SYSTEM (SWS) | 15 |
| 3-2. | FLOW DIAGRAM OF BIOTROL AQUEOUS TREATMENT SYSTEM (BATS) | 17 |
| 3-3. | BIOTROL INC. MOBILE AQUEOUS TREATMENT SYSTEM | 18 |
| 3-4. | SCHEMATIC OF BIOREACTOR | 19 |
| 3-5. | FLOW DIAGRAM OF THE SLURRY BIO-REACTOR (SBR) WITH SAMPLE POINTS | 21 |
| 3-6. | SLURRY BIO-REACTOR PROCESS DIAGRAM | 22 |
| 4-1. | FLOW DIAGRAM OF THE BIOTROL SOIL WASHING SYSTEM (BSWS) | 25 |
| 4-2. | PARTICLE-SIZE FRACTION ANALYSIS | 43 |
| 4-3. | PARTICLE-SIZE FRACTION ANALYSIS | 48 |
| 4-4. | PARTICLE-SIZE FRACTION ANALYSIS | 49 |
| 4-5. | MASS DISTRIBUTION IN LOW PENTA SW TEST | 56 |
| 4-6. | DISTRIBUTION OF OUTPUT MASS - LOW PENTA SW TEST | 57 |
| 4-7. | MASS DISTRIBUTION IN HIGH PENTA SW TEST | 60 |
| 4-8. | DISTRIBUTION OF OUTPUT MASS - HIGH PENTA SW TEST | 61 |
| 4-9. | PENTA CONCENTRATION IN OUTPUT STREAMS - LOW PENTA SW TEST | 63 |
| 4-10. | PENTA CONCENTRATION IN OUTPUT STREAMS - HIGH PENTA SW TEST | 66 |
| 4-11. | METALS IN LOW PENTA SW TEST | 79 |
| 4-12. | METALS IN HIGH PENTA SW TEST | 79 |
| 4-13. | SOLIDS STREAM RATES - LOW PENTA SW TEST | 84 |
| 4-14. | AQUEOUS STREAM RATES - LOW PENTA SW TEST | 85 |
| 4-15. | SOLIDS STREAMS - HIGH PENTA SW TEST | 86 |
| 4-16. | AQUEOUS STREAM - HIGH PENTA SW TEST | 87 |
| 4-17. | WASHED SOIL AND FEED SOIL PENTA CONC. - LOW PENTA SW TEST | 89 |
| 4-18. | WASHED SOIL AND FEED SOIL PENTA CONC. - HIGH PENTA SW TEST | 91 |
| 4-19. | BATS - LOW PENTA TEST - PENTACHLOROPHENOL CONCENTRATION | 96 |
| 4-20. | BATS - HIGH PENTA TEST - PENTACHLOROPHENOL CONCENTRATION | 97 |
| 4-21. | SBR - PENTA REMOVAL EFFICIENCY | 123 |
| 4-22. | SBR - PENTA IN LIQUID PHASE OF INFLUENT | 124 |
| 4-23. | SBR - PENTA IN SOLID PHASE OF INFLUENT | 125 |
| 4-24. | SBR - OVERALL PENTA REMOVAL EFFICIENCY | 128 |
| 4-25. | SBR - ACENAPHTHENE INFLUENT SOLID PHASE | 136 |
| 4-26. | SBR - FLUORANTHENE INFLUENT SOLID PHASE | 136 |
| 4-27. | SBR - PYRENE INFLUENT SOLID PHASE | 136 |
| 4-28. | SBR - BENZO(A)ANTHRACENE INFLUENT SOLID PHASE | 136 |
| 4-29. | SBR - CHRYSENE INFLUENT SOLID PHASE | 137 |
| 4-30. | SBR - BENZO(A)PYRENE INFLUENT SOLID PHASE | 137 |

## LIST OF FIGURES (CONT'D)


| | | PAGE |
|---|---|---|
| 4-31. | ACENAPHTHENE REMOVAL EFFICIENCY | 145 |
| 4-32. | FLUORANTHENE REMOVAL EFFICIENCY | 146 |
| 4-33. | PYRENE REMOVAL EFFICIENCY | 147 |
| 4-34. | BENZO(A)ANTHRACENE REMOVAL EFFICIENCY | 148 |
| 4-35. | CHRYSENE REMOVAL EFFICIENCY | 149 |
| 4-36. | BENZO(B)FLUORANTHENE REMOVAL EFFICIENCY | 150 |
| 4-37. | BENZO(A)PYRENE REMOVAL EFFICIENCY | 151 |
| 4-38. | SLURRY BIO-REACTOR - pH DATA | 166 |
| 4-39. | SLURRY BIO-REACTOR - POWER USAGE | 167 |

## LIST OF TABLES


| TABLE | | PAGE |
|---|---|---|
| 2-1. | SUMMARY OF CONTAMINANT REMOVAL EFFICIENCIES | 9 |
| 4-1. | SOIL WASHER FIELD MEASUREMENTS | 29 |
| 4-2. | BIOTROL AQUEOUS TREATMENT SYSTEM FIELD MEASUREMENTS | 30 |
| 4-3. | SLURRY BIO-REACTOR FIELD MEASUREMENTS | 31 |
| 4-4. | ANALYTICAL METHODS USED DURING THE BSWS SITE DEMONSTRATION | 33 |
| 4-5. | SOIL WASHER SAMPLES | 36 |
| 4-6. | BIOTROL AQUEOUS TREATMENT SYSTEM SAMPLES | 37 |
| 4-7. | SLURRY BIO-REACTOR SAMPLES | 37 |
| 4-8. | LOW PENTA SOIL PILE CHARACTERISTICS | 39 |
| 4-9. | HIGH PENTA SOIL PILE CHARACTERISTICS | 40 |
| 4-10. | PARTICLE-SIZE ANALYSIS OF LOW PENTA SW | 41 |
| 4-11. | CHEMICAL ANALYSIS OF PARTICLE-SIZE FRACTION - LOW PENTA CONCENTRATION SOIL SAMPLE | 42 |
| 4-12. | PARTICLE-SIZE ANALYSIS OF HIGH PENTA CONCENTRATION SOIL SODIUM HEXAMETAPHOSPHATE SIEVING SOLUTION | 45 |
| 4-13. | PARTICLE-SIZE ANALYSIS OF HIGH PENTA CONCENTRATION SOIL - ASTM TYPE II WATER SIEVING SOLUTION | 45 |
| 4-14. | CHEMICAL ANALYSIS OF PARTICLE-SIZE FRACTIONS - HIGH PENTA CONCENTRATION SOIL SAMPLE SODIUM HEXAMETHAPHOSPHATE SIEVING SOLUTION | 46 |
| 4-15. | CHEMICAL ANALYSIS OF PARTICLE-SIZE FRACTIONS - HIGH CONCENTRATION SOIL SAMPLE ASTM TYPE II WATER SIEVING SOLUTION | 47 |
| 4-16. | PARTICLE-SIZE ANALYSIS AND CHEMICAL ANALYSIS OF SOLID PROCESS STREAMS - LOW PENTA SW TEST | 50 |
| 4-17. | PARTICLE-SIZE ANALYSIS AND CHEMICAL ANALYSIS OF SOLID PROCESS STREAMS - HIGH PENTA SW TEST | 51 |
| 4-18. | COMPARISON OF AVERAGE AND WEIGHTED CONCENTRATIONS | 53 |
| 4-19. | FATE OF MATERIALS - LOW PENTA SW TEST | 55 |
| 4-20. | FATE OF MATERIALS - HIGH PENTA SW TEST | 59 |
| 4-21. | AVERAGE PENTA DISTRIBUTION - LOW PENTA SW TEST | 62 |
| 4-22. | AVERAGE PENTA DISTRIBUTION - HIGH PENTA SW TEST | 65 |
| 4-23. | AVERAGE PAH CONCENTRATION AND MASS - LOW SW TEST | 68 |
| 4-24. | AVERAGE PAH CONCENTRATION AND MASS - HIGH SW TEST | 72 |
| 4-25. | COMPARISON OF PENTA AND PAH DISTRIBUTION IN OUTPUT STREAMS | 77 |
| 4-26. | AVERAGE METALS BALANCE-LOW PENTA SW TEST | 78 |
| 4-27. | AVERAGE METALS BALANCE-HIGH PENTA SW TEST | 78 |
| 4-28. | EP TOXICITY TEST RESULTS - LOW PENTA SW TEST | 81 |
| 4-29. | EP TOXICITY TEST RESULTS - HIGH PENTA SW TEST | 82 |
| 4-30. | FEED SOIL RATE - LOW PENTA SW TEST | 90 |
| 4-31. | BATS - LOW PENTA TEST SYSTEM PERFORMANCE AND MATERIAL INVENTORY-PENTACHLOROPHENOL | 93 |
| 4-32. | BATS - HIGH PENTA TEST SYSTEM PERFORMANCE AND MATERIAL INVENTORY - PENTACHLOROPHENOL | 95 |
| 4-33. | BATS - LOW PENTA TEST SYSTEM PERFORMANCE AND MATERIAL INVENTORY-ANTHRACENE | 98 |

## LIST OF TABLES


| | | PAGE |
|---|---|---|
| 4-34. | BATS - LOW PENTA TEST SYSTEM PERFORMANCE AND MATERIAL INVENTORY - ARSENIC, CHROMIUM AND COPPER | 100 |
| 4-35. | BATS - HIGH PENTA TEST SYSTEM PERFORMANCE AND MATERIAL INVENTORY - ARSENIC, CHROMIUM AND COPPER | 101 |
| 4-36. | BATS PENTA MINERALIZATION ASSESSMENT | 103 |
| 4-37. | BATS - LOW PENTA TEST MATERIAL INVENTORY-TOTAL SOLIDS | 105 |
| 4-38. | BATS - HIGH PENTA TEST MATERIAL INVENTORY - TOTAL SOLIDS | 106 |
| 4-39. | BATS - LOW PENTA TEST MATERIAL INVENTORY - TOTAL RECOVERABLE PETROLEUM HYDROCARBONS | 107 |
| 4-40. | BATS - HIGH PENTA TEST MATERIAL INVENTORY - TOTAL RECOVERABLE PETROLEUM HYDROCARBONS | 108 |
| 4-41. | BATS - LOW PENTA TEST MATERIAL INVENTORY - CHEMICAL OXYGEN DEMAND (COD) | 109 |
| 4-42. | BATS - HIGH PENTA TEST MATERIAL INVENTORY - CHEMICAL OXYGEN DEMAND (COD) | 110 |
| 4-43. | BATS LOW PENTA TEST - SYSTEM FIELD MEASUREMENTS | 112 |
| 4-44. | BATS HIGH PENTA TEST - SYSTEM FIELD MEASUREMENTS | 113 |
| 4-45. | SBR TIME-WEIGHTED MASS & VOLUME BALANCE | 117 |
| 4-46. | SBR LIQUID PHASE PENTA DATA | 121 |
| 4-47. | SBR SOLID PHASE PENTA DATA | 122 |
| 4-48. | OVERALL PENTA REDUCTION IN SBR | 126 |
| 4-49. | SBR INFLUENT LIQUID PHASE PAH DETECTION LIMITS | 129 |
| 4-50. | SBR EFFLUENT LIQUID PHASE PAH DETECTION LIMITS | 130 |
| 4-51. | SBR INFLUENT SOLID PHASE PAH DATA | 131 |
| 4-52. | SBR EFFLUENT SOLID PHASE PAH DATA | 132 |
| 4-53. | SOLID PHASE PAH RESULTS SUMMARY | 134 |
| 4-54. | ACENAPHTHENE REMOVAL EFFICIENCY | 137 |
| 4-55. | FLUORANTHENE REMOVAL EFFICIENCY | 138 |
| 4-56. | PYRENE REMOVAL EFFICIENCY | 139 |
| 4-57. | BENZO(A)ANTHRACENE REMOVAL EFFICIENCY | 140 |
| 4-58. | CHRYSENE REMOVAL EFFICIENCY | 141 |
| 4-59. | BENZO(B)FLUORANTHENE REMOVAL EFFICIENCY | 142 |
| 4-60. | BENZO(B)FLUORANTHENE REMOVAL EFFICIENCY | 143 |
| 4-61. | PAH REMOVAL SUMMARY | 153 |
| 4-62. | SBR ARSENIC, CHROMIUM & COPPER MATERIAL BALANCES | 154 |
| 4-63. | SBR TOTAL RECOVERABLE PETROLEUM HYDROCARBON MATERIAL BALANCE | 155 |
| 4-64. | SBR CHEMICAL OXYGEN DEMAND | 156 |
| 4-65. | SBR TOTAL SOLIDS | 158 |
| 4-66. | SBR TOTAL SOLIDS BALANCE | 159 |

## LIST OF TABLES


| | | PAGE |
|---|---|---|
| 4-67. | SBR TOTAL ORGANIC HALIDES MATERIAL BALANCE | 160 |
| 4-68. | SBR CHLORIDE MATERIAL BALANCE | 162 |
| 4-69. | SBR EFFLUENT METALS CONCENTRATIONS | 163 |
| 4-70. | SBR EFFLUENT EP TOXICITY ANALYSIS | 164 |
| 4-71. | SBR PH DATA | 165 |
| 4-72. | SBR POWER USAGE | 167 |
| 4-73. | TOTAL CDD/CDF DATA -LOW PENTA SW TEST | 170 |
| 4-74. | TOTAL CDD/CDF DATA -HIGH PENTA SW TEST | 170 |
| 4-75. | CDD/CDF DISTRIBUTION - LOW PENTA SW TEST | 171 |
| 4-76. | BATS - CDD/CDF CONCENTRATIONS IN THE EFFLUENT STREAMS | 174 |
| 4-77. | SLURRY BIO-REACTOR - CDD/CDF CONCENTRATIONS IN THE EFFLUENT STREAMS | 175 |
| 5-1. | "ORDER-OF-MAGNITUDE" COST ESTIMATE FOR A HYPOTHETICAL DEMONSTRATION TEST AT A "GENERIC" SITE | 180 |
| 6-1. | ACCURACY - SURROGATE SPIKES SOIL WASHER LOW CONCENTRATION SOIL TEST | 188 |
| 6-2. | ACCURACY - SURROGATE SPIKES SOIL WASHER HIGH CONCENTRATION SOIL TEST | 189 |
| 6-3. | PENTACHLOROPHENOL MS/MSD RESULTS - PRECISION | 191 |
| 6-4. | MS/MSD DATA FOR SOIL WASHER (SOIL AND AQUEOUS MATRICES) PAH COMPOUNDS ONLY | 192 |
| 6-5. | QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, EP TOXICITY SOIL PILE SAMPLES (1) | 198 |
| 6-6. | COMPLETENESS SOIL PILES | 200 |
| 6-7. | QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, EP TOXICITY SOIL WASHER SAMPLES | 202 |
| 6-8. | LOW CONCENTRATION SOIL DEMONSTRATION - PRECISION (FIELD DUPLICATES) | 205 |
| 6-9. | HIGH CONCENTRATION SOIL DEMONSTRATION - PRECISION (FIELD DUPLICATES) | 206 |
| 6-10. | "COMPLETENESS SOIL WASHER"; LOW CONC. SOIL DEMONSTRATION | 208 |
| 6-11. | "COMPLETENESS SOIL WASHER"; HIGH CONC. SOIL DEMONSTRATION | 209 |
| 6-12. | ACCURACY - SURROGATE SPIKES, AQUEOUS TREATMENT SYSTEM (AT INFLUENT AND EFFLUENT SAMPLES) | 211 |
| 6-13. | MS/MSDS FOR ORGANICS ON ATS EFFLUENT SAMPLES | 212 |
| 6-14. | | |
| 6-15. | COMPLETENESS FOR AQUEOUS TREATMENT SYSTEM (ATS) | 216 |
| 6-16. | ATS FIELD MEASUREMENTS: COMPLETENESS | 217 |
| 6-17. | ACCURACY - SURROGATE SPIKES SLURRY BIOREACTOR (SOIL FRACTION) | 219 |
| 6-18. | ACCURACY - SURROGATE SPIKES SLURRY BIOREACTOR (WATER FRACTION) | 220 |
| 6-19. | MS/MSD DATA FOR SLURRY BIOREACTOR INFLUENT (PAH COMPOUNDS ONLY) | 221 |

## LIST OF TABLES


| | | PAGE |
|---|---|---|
| 6-20. | QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, EP TOXICITY SOIL SLURRY BIOREACTOR SAMPLES | 223 |
| 6-21. | PRECISION SLURRY BIOREACTOR FIELD DUPLICATES | 224 |
| 6-22. | "COMPLETENESS" SLURRY BIOREACTOR | 228 |
| 6-23. | HOLDING TIME STUDY FOR FEED SOIL | 232 |
| 6-24. | HOLDING TIME STUDY FOR WASHED SAND | 233 |
| 6-25. | HOLDING TIME STUDY FOR COARSE OVERSIZED | 234 |
| 6-26. | HOLDING TIME STUDY FOR FINE PARTICLE CAKE | 235 |
| 6-27. | HOLDING TIME STUDY FOR FINE OVERSIZE | 236 |
| 6-28. | HOLDING TIME STUDY FOR SLURRY PHASE | 240 |
| 6-29. | HOLDING TIME STUDY FOR SLURRY AQUEOUS PHASE | 241 |

## TABLE OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| AAS | atomic absorption spectroscopy |
| ASTM | American Society for Testing and Materials |
| BATS | BioTrol Aqueous Treatment System |
| BOD | biochemical oxygen demand |
| BSWS | BioTrol Soil Washer System |
| CCA | chromated copper arsenate |
| CDE | Combined Dewatering Effluent |
| CEC | cation exchange capacity |
| COD | chemical oxygen demand |
| CV | coefficient of variation |
| DFTPP | decafluorotriphenylphosphine |
| DO | dissolved oxygen |
| EP Tox | Extraction Procedure Toxicity (test) |
| EPA | Environmental Protection Agency |
| gal | gallon(s) |
| GC | gas chromatography |
| gpm | gallons per minute |
| kg | kilogram(s) |
| kw | kilowatt(s) |
| L | liter(s) |
| MDL | method detection limit |
| mg | milligram(s) |
| $MgSO_4 \cdot H_2O$ | magnesium sulfate monohydrate |
| ml | milliliter |
| mm | millimeter(s) |
| MN | Minnesota |
| MS | mass spectrometry |
| MS/MSD | matrix spike and matrix spike duplicate |
| MPCA | Minnesota Pollution Control Agency |
| MTLS | metals, other than arsenic, chromium and copper |
| NBS | National Bureau of Standards (now NIST) |
| NIST | National Institute of Standards and Technology |
| No. | number |
| PAH | polynuclear aromatic hydrocarbon |
| PCDD | polychlorinated dibenzodioxins (also CDD) |
| PCDF | polychlorinated dibenzofurans (also CDF) |
| penta | pentachlorophenol |
| PFTBA | perfluorotributylamine |
| pH | - logarithm [hydrogen ion concentration] |
| PM | Project Manager |

## TABLE OF ABBREVIATIONS AND SYMBOLS (continued)

| | |
|---|---|
| ppb | parts per billion |
| ppm | parts per million |
| PVC | polyvinyl chloride |
| QA | quality assurance |
| QAPjP | quality assurance project plan |
| QAPP | quality assurance program plan |
| QC | quality control |
| RCRA | Resource Conservation and Recovery Act |
| RE | relative error |
| RPD | relative percent difference |
| RREL | Risk Reduction Engineering Laboratory |
| SAIC | Science Applications International Corporation |
| SBR | Slurry Bio-Reactor |
| SITE | Superfund Innovative Technology Evaluation (Program) |
| STD | standard |
| SW | Soil Washer |
| SW-xxxx | EPA SW-846 method number xxxx |
| TOC | total organic carbon |
| TRPH | total recoverable petroleum hydrocarbons |
| ug | microgram |
| um | micrometer(s) |
| °C | degrees Celsius |
| < | less than |
| > | greater than |
| ≥ | greater than or equal to |

## CONVERSION FACTORS

| | English (US) | x | Factor | = | Metric |
|---|---|---|---|---|---|
| Area: | 1 $ft^2$ | x | $9.29 \times 10^{-2}$ | = | $m^2$ |
| | 1 $in^2$ | x | 6.45 | = | $cm^2$ |
| Flow Rate: | 1 gal/min | x | $6.31 \times 10^{-5}$ | = | $m^3/s$ |
| | 1 gal/min | x | $6.31 \times 10^{-2}$ | = | L/s |
| | 1 Mgal/d | x | 43.8 | = | L/s |
| | 1 Mgal/d | x | $3.78 \times 10^{3}$ | = | $m^3/d$ |
| | 1 Mgal/d | x | $4.38 \times 10^{-2}$ | = | $m^3/s$ |
| Length: | 1 ft | x | 0.30 | = | m |
| | 1 in | x | 2.54 | = | cm |
| | 1 yd | x | 0.91 | = | m |
| Mass: | 1 lb | x | $4.54 \times 10^{2}$ | = | g |
| | 1 lb | x | 0.454 | = | kg |
| Volume: | 1 $ft^3$ | x | 28.3 | = | L |
| | 1 $ft^3$ | x | $2.83 \times 10^{-2}$ | = | $m^3$ |
| | 1 gal | x | 3.78 | = | L |
| | 1 gal | x | $3.78 \times 10^{-3}$ | = | $m^3$ |

ft = foot, $ft^2$ = square foot, $ft^3$ = cubic foot
in = inch, $in^2$ = square inch
yd = yard
lb = pound
gal = gallon
gal/min (or gpm) = gallons per minute
Mgal/d (or MGD) = million gallons per day
m = meter, $m^2$ = square meter, $m^3$ = cubic meter
cm = centimeter, $cm^2$ = square centimeter
L = liter
g = gram
kg = kilogram
$m^3/s$ = cubic meters per second
L/s = liters/sec
$m^3/d$ = cubic meters per day

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# SECTION 1

# INTRODUCTION

## 1.1 THE SITE PROGRAM

In 1986, the EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) established the SITE Program to promote the development and use of innovative technologies to clean up Superfund sites across the country. Now in its sixth year, the SITE program is helping to provide the treatment technologies necessary to implement new Federal and State cleanup standards aimed at permanent remedies. The SITE program is composed of three elements: the Demonstration Program, the Emerging Technologies Program, and an Analytical Methods Development Program.

The major focus has been on the Demonstration Program, which is designed to provide engineering and cost data on selected technologies. EPA and developers participating in the program share the cost of the demonstration. Developers are responsible for demonstrating their innovative systems at chosen sites, usually Superfund sites. EPA is responsible for sampling, analyzing, and evaluating all test results. The result is an assessment of the technology's performance that can be used in conjunction with other data to select the most appropriate technologies for the cleanup of Superfund and otherwise contaminated sites.

Developers of innovative technologies apply to the Demonstration Program by responding to EPA's annual solicitation. EPA also will accept proposals at any time when a developer has a treatment project scheduled with Superfund waste. To qualify for the program, a new technology must be at the pilot- or full-scale stage of development and offer some advantage over existing technologies. Mobile technologies are of particular interest to EPA.

Once EPA has accepted a proposal, EPA and the developer work with the EPA regional offices and State agencies to identify a site containing wastes suitable for testing the capabilities of the technology. EPA then prepares a detailed sampling and analysis plan designed to evaluate the technology thoroughly and to ensure that the resulting data are reliable. The duration of a demonstration varies from a few days to several months, depending on the type of process and quantity of waste needed to assess the technology. On completion of a demonstration, EPA prepares a Technology Evaluation Report and an Applications Analysis Report.

The Technology Evaluation Report compiles and summarizes the results of the SITE demonstration including the vendor's design and test data, a detailed technology description, the site and waste used for the demonstration, and

sampling and analysis during the test. Costs of the technology are estimated based on data from the demonstration and other pilot- and full-scale applications. The report discusses the factors, such as site and waste characteristics, that have a major impact on costs and performance. The Applications Analysis Report more briefly explains the technology and the results obtained. This report strives to evaluate the applicability of the vendor's technology to other sites and other wastes. Ultimately, with the Technology Evaluation Report and the Applications Analysis Report, the Demonstration Program leads to an analysis of the technology's overall applicability to Superfund problems.

## 1.2 OBJECTIVES OF THE DEMONSTRATION

The objectives of this SITE demonstration of BioTrol's soil washing technology at the MacGillis & Gibbs Superfund site were to evaluate the following:

1. Performance of the three technologies that made up the treatment train in this test, particularly in terms of pentachlorophenol (penta) and polynuclear aromatic hydrocarbon (PAH) contaminant reduction efficiencies.

2. Fate of contaminants in the SW through the use of a material balance.

3. Fate of contaminants in the BATS and SBR through the use of a material inventory.

4. Effect of process operating conditions on performance.

5. Potential health and safety impacts resulting from system operation.

6. Equipment and material handling problems.

7. Projected system economics and major contributing factors.

8. Applicability of the this arrangement of technologies to other contaminants.

## 1.3 SITE DESCRIPTION

The Site demonstration of the BioTrol soil washing system was conducted at the MacGillis & Gibbs Superfund site in New Brighton, Minnesota. The MacGillis & Gibbs Company has been operating a wood treatment facility on this site since approximately 1920. Contaminants present at the site include polynuclear aromatic hydrocarbons (PAHs) from creosote, a coal-tar distillate, penta, and chromium, copper, and arsenic from chromated copper arsenate (CCA) used most recently for wood treatment. Wood preserving operations were on-going

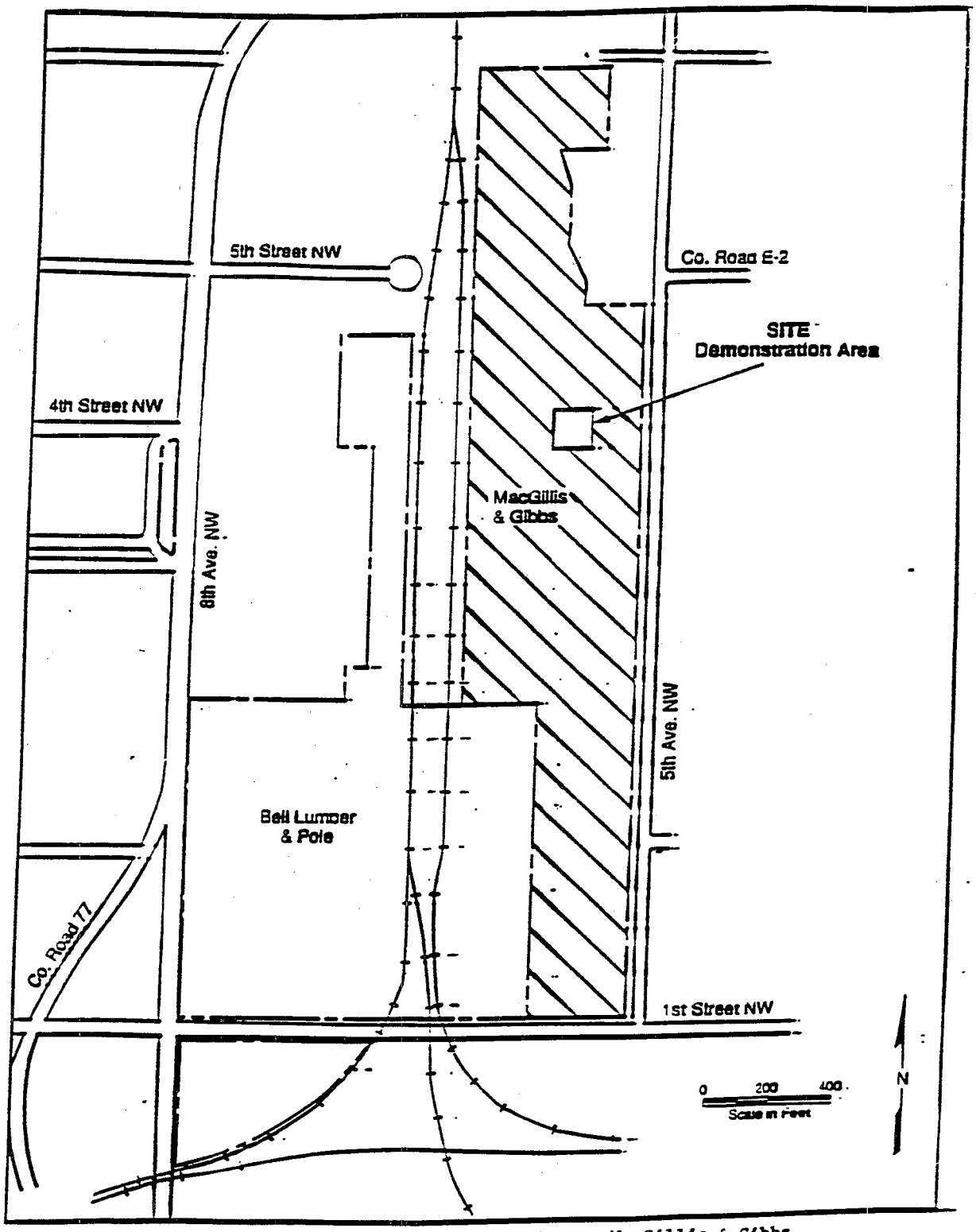


FIGURE 1-1. SITE Demonstration Location at MacGillis & Gibbs

at this site throughout the course of this demonstration. Section 4 contains a more detailed site description.

Detailed process descriptions of the three technologies are presented in Section 3 along with flow diagrams. The sampling and analytical program for the tests is summarized in Section 4.

## 1.4 DESCRIPTION OF OPERATIONS

Contaminated soils excavated from two locations at the MacGillis & Gibbs site were processed by the BSWS. A soil with a high penta concentration (680 ppm penta) was excavated from the disposal area shown in Figure 1-2 and a soil with a low penta concentration (35 ppm) excavated from another area and mixed with more highly contaminated soil previously excavated by BioTrol to form a soil with an average of 130 ppm penta. Both soil piles were screened to remove particles greater than $^3/_8$" in size and thoroughly mixed to form the high penta concentration feed soil pile and the low penta concentration Feed Soil pile. For convenience these will be referred to as the "High Penta" soil (680 ppm penta) and the "Low Penta" soil (130 ppm penta).

Two tests of the SW were conducted. The first test using the Low Penta soil lasted for 48 hours (2 days). The second test using the High Penta soil lasted for 150 hours (6 days and 18 hours) but testing of the system was carried out over about 112 hours. The process steps included screening, mixing, froth flotation, attrition/classification, thickening, and dewatering. Soils were fed via conveyor belt at an average rate of 220 kg/hr (484 lb/hr) for the Low Penta SW test and 160 kg/hr (352 lb/hr) for the High Penta SW test. Feed rates varied as a result of necessary equipment adjustments.

The BATS demonstration also consisted of two tests. During the first test, which lasted 89 hours (approximately 4 days), contaminated SW process water (about 15 ppm penta) from the Low Penta soil washer test was treated in the BATS. During the second test, which lasted 148 hours (approximately 6 days), contaminated SW process water from the High Penta soil washer test (about 45 ppm penta) was treated in the BATS. The process steps included nutrient addition, pH adjustment and a single pass through the BATS reactor. The treated water was recycled to the SW starting on the first day of the High Penta SW test. Flowrate through the BATS was approximately 10 L/min (3 gpm) for both BATS tests.

While the SW and the BATS were compatible in size, the SBR was considerably smaller, consequently it was tested only on a portion of the fine particle slurry during the High Penta SW test. On the third day of the High Penta SW test, the underflow from the fine particle thickener was diverted from the SW to a holding tank to be used as feed to the SBR. The test of the SBR lasted fourteen days. The process steps included nutrient addition and pH adjustment while the slurry was passing through the cascading reactor system and a final dewatering step. Flow through the SBR was approximately 24 ml/min (0.006 gpm) and the retention time in the SBR reactor was 4-6 days.

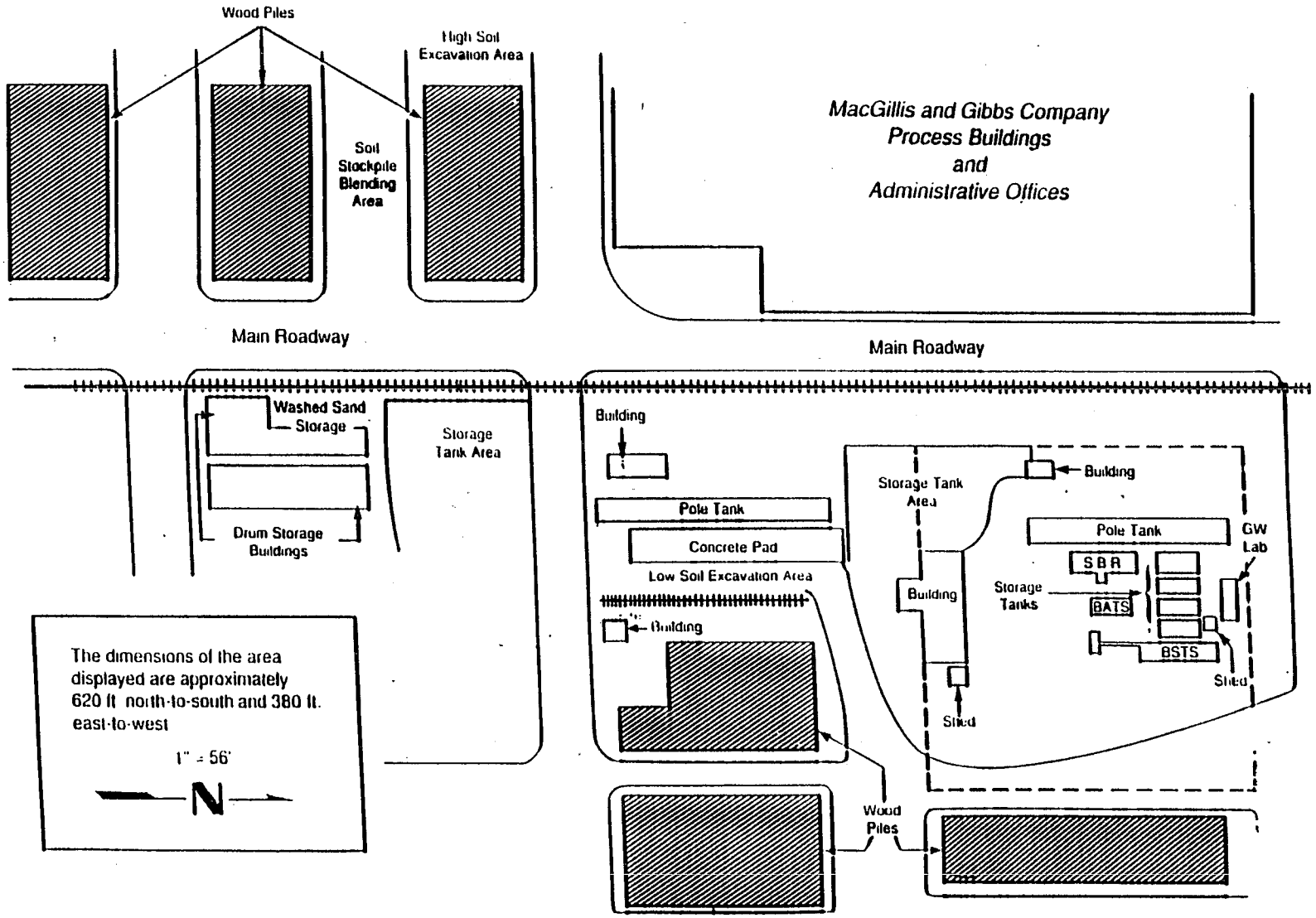


FIGURE 1-2. **MacGillis and Gibbs/Biotrol Site Map**

## 1.5 PROJECT ORGANIZATION

Through a Cooperative Agreement between EPA and BioTrol Inc., BioTrol was responsible for operating their equipment while EPA was responsible for conducting the demonstration through its SITE Contractor, SAIC. The demonstration included the following activities:

- preparation of the demonstration test plan
- preparation of the test site to support testing, equipment setup, and health and safety orientation of field staff
- excavation and preparation of feed soils
- predemonstration sampling and analysis of feed soils
- preparation for analysis of samples
- sampling during the tests of BioTrol's equipment
- Public information meeting held to review BioTrol's soil washing technology and tests on soils from the MacGillis & Gibbs site.
- two SW tests, two BATS tests, and one SBR test
- Visitors' Day
- post demonstration sampling and analysis of the test staging area soils
- site closure and disposal of waste materials
- preparation of a Technology Evaluation Report and an Applications Analysis Report.

Figure 1-3 illustrates the project organization for this demonstration.

### 1.5.1 Key Contacts

Information useful to potential technology users can be provided by the following sources:

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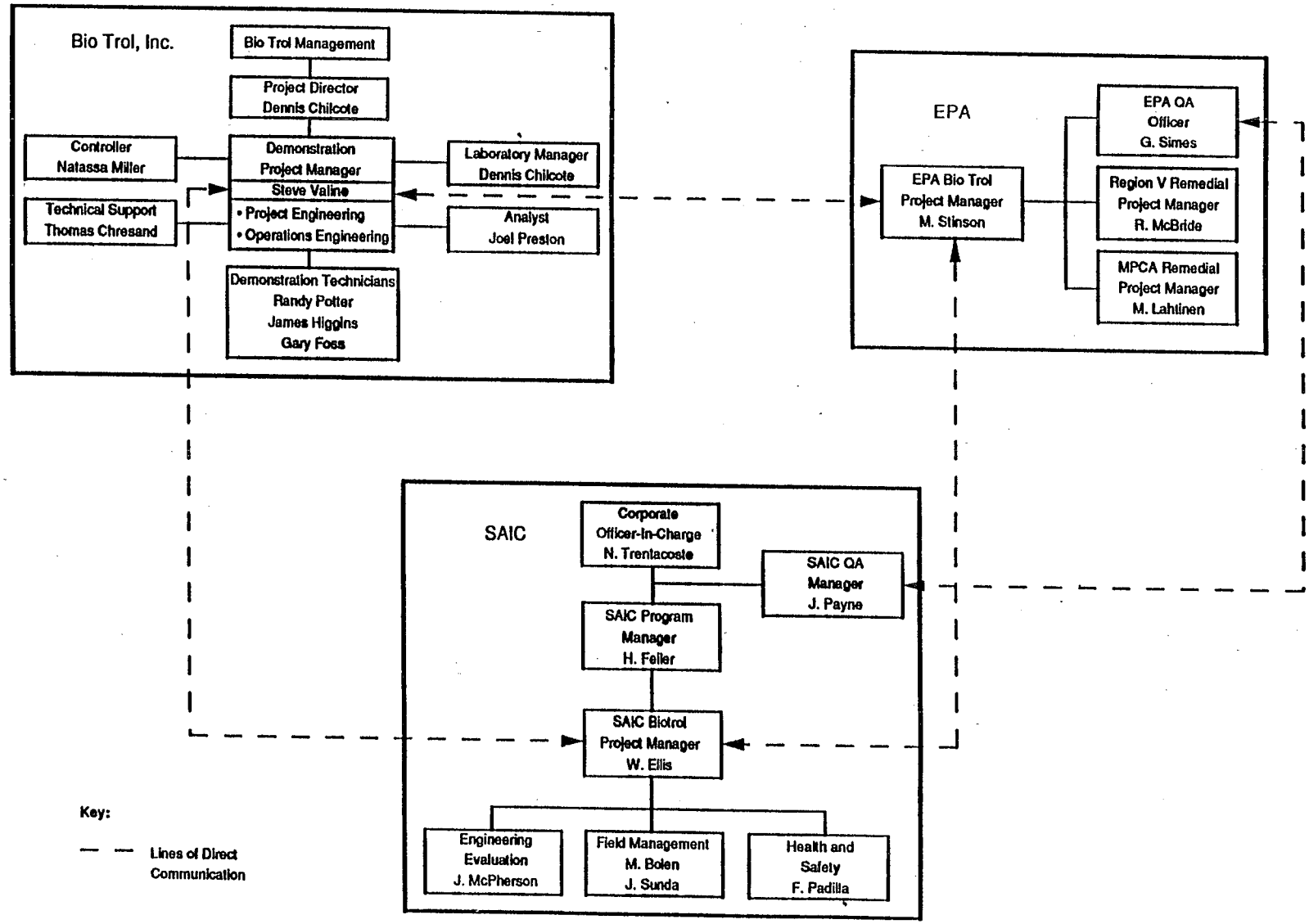


FIGURE 1-3. **Project Organization**

## SECTION 2

## EXECUTIVE SUMMARY

### 2.1 SITE DEMONSTRATION

This demonstration evaluated the individual components of a soil treatment system developed by BioTrol, Inc., of Chaska, Minnesota. For this study, a Soil Washer (SW), the BioTrol Aqueous Treatment System (BATS), and a Slurry Bio-Reactor (SBR) were arranged to represent integrated operation to provide a complete remedial alternative. Soil is fed to the SW and mixed with water. This slurry is subjected to a series of screening, mixing, froth flotation, attrition/classification, thickening, and dewatering steps. This separates the relatively clean coarse particles from the more heavily contaminated fine particles (clay and silt) and also provides scrubbing and extraction. Contaminated woody debris is segregated during the soil washing. Resulting process water is treated in the BATS, a three-celled, packed bed reactor where contaminants are removed via biological degradation. The heavily contaminated fine particles are biologically treated as a slurry in the SBR, which consists of three aerated reactors arranged in a cascading system. this unit was provided by EIMCO Process Equipment Company. While the SW and BATS are compatible in capacity, the SBR is considerably smaller.

The demonstration was conducted at the MacGillis & Gibbs Superfund site in New Brighton, Minnesota. The site has been an active wood preserving facility since the 1920s. Operational and waste disposal practices (now improved) have contaminated the soil and the groundwater at the site with the pentachlorophenol, creosote-based polynuclear aromatic hydrocarbons, and copper, chromium, and arsenic chemicals used as wood preservatives over the course of the facility's history.

The demonstration lasted a total of 5 weeks with the tests of individual technologies lasting approximately 2 weeks each. A total of 29,000 kg (32 short tons) of contaminated soil was processed in the SW along with 148,000 L (38,900 gal) of process water in the BATS and 315 L (83 gal) of fine particle slurry in the SBR.

The demonstration of the BSWS was conducted through the U.S. Environmental Protection Agency's (EPA's) Superfund Innovative Technology Evaluation (SITE) program to develop reliable performance and cost data. The data collected from this SITE demonstration test will be used to make sound decisions as to the applicability of the process to other contaminated sites. Specifically, the information from this demonstration will be used to:

- characterize the efficiency of the Soil Washer and the two companion technologies
- evaluate potential uses of soil washing for other remedial actions
- identify pretreatment requirements
- isolate operational problems and potential solutions
- characterize process residues
- identify the need for secondary treatment
- develop operating costs for the pilot-scale unit and determine scale-up costs for a commercial unit
- identify pertinent Government policy and regulatory requirements
- provide a basis for comparison to competitive technologies

## 2.2 SUMMARY OF RESULTS

### 2.2.1 Soil Washer

The Soil Washer (SW) was used to treat soils contaminated with pentachlorophenol (penta), polynuclear aromatic hydrocarbons (PAHs), and heavy metals (chromium, copper, and arsenic). The demonstration consisted of tests of two soil piles: a Low Penta soil (130 ppm penta) and a High Penta soil (680 ppm penta). Removal efficiencies were calculated as:

100 [1-(Washed Soil output/Feed Soil input)]

where input and output refer to concentration or mass of contaminant. The Washed Soil is the major solids output stream. The results are summarized in the following table.

TABLE 2-1. SUMMARY OF CONTAMINANT REMOVAL EFFICIENCIES
(based on concentrations)

| test | Feed Rate kg/hr | penta % | PAHs % | c-PAHs % | TOC % | Cu % | Cr % | As % |
|---|---|---|---|---|---|---|---|---|
| Low Penta | 220 | 89 | 83 | 81 | 84 | 59 | 46 | 61 |
| High Penta | 160 | 87 | 88 | 87 | 81 | 72 | 66 | 56 |

Within the precision of the averaged results for each test, Soil Washer removal efficiency was not seriously affected by fluctuations in either Feed Soil contaminant concentration or Feed Soil flow rate. It should, however, be noted that there were significant discrepancies in the penta mass balance, with much more penta reported in the output streams than in the input. While not verified, the difference in accessibility for extraction and analysis before and after the soil washing may be a major contributor to these discrepancies.

### 2.2.2 BioTrol Aqueous Treatment System

The BioTrol Aqueous Treatment System was used to treat Soil Washer process water. In the first test, using process water with about 15 ppm penta from the Low Penta SW test, the BATS achieved a removal efficiency of 91% for penta (based on weighted masses) at an average flow rate of 10.2 L/min (2.69 gpm). In the second test, using process water with about 44 ppm penta from the High Penta SW test, the BATS achieved a removal efficiency of 94% for penta (weighted masses) at an average flow rate of 10.3 L/min (2.72 gpm). The total volumes treated in the two tests were 55,400 L (14,600 gal) and 92,200 L (24,400 gal), respectively. The treated effluent was recycled to the SW as process water during the demonstration.

### 2.2.3 Slurry Bio-Reactor

The Slurry Bio-Reactor tested had a much smaller capacity than the other two technologies. At a constant flow rate of 24 ml/min and a volume of 180 liters, the average retention time was approximately 5.2 days. However, complete acclimation apparently was not achieved until well into the test and steady state operation was not reached. Nevertheless, penta removal did reach at least 90% and probably would have stabilized at or above this level had the test been continued. PAH removal efficiency reached at least 70% for all compounds of interest after acclimation. Heavy metals were unaffected.

## 2.3 CONCLUSIONS

### 2.3.1 Soil Washer

Based on the results of this demonstration, the following conclusions can be reached regarding the operation of the Soil Washer:

- The largest solid output stream, the Washed Soil, retains only a relatively small portion (~10%) of the original pentachlorophenol mass.
- Penta and PAH removal efficiencies of 87-89% and 83-88%, respectively, can be achieved with soils of different initial concentrations.
- Contaminant concentrations in the Washed Soil output stream appear to be steady within a narrow range for each Feed Soil tested and seem to be independent of fluctuations in the concentration range of the Feed Soil.
- Pentachlorophenol accumulates largely in the process water (Combined Dewatering Effluent, CDE) and the clay and silt fines (Fine Particle Cake, FPC). Both of these output streams can be treated biologically (e.g., BATS and SBR). Water-insoluble compounds such as PAHs gather mostly on the Fine Particle Cake.
- The Soil Washer did experience some operational instability, primarily with the feed delivery system. BioTrol feels that this problem is correctable.

### 2.3.2 BioTrol Aqueous Treatment System

Based on the results of this demonstration and previous tests conducted by BioTrol, the following conclusions can be reached regarding the operation of the BATS:

- Results of the tests at two different penta concentrations verify the vendor's claim that the system can achieve removals of >90% of pentachlorophenol extracted into the process water by the soil washing process.

- The claim that polynuclear aromatic hydrocarbons are removed by the system cannot be substantiated from this demonstration because the concentrations of most PAHs, even in the influent, were below detection limits (2-15 ppb in the Low Penta test and 1-400 ppb in the High Penta test).

- The system is unaffected by increases (up to 90 ppm) in the concentrations of copper, chromium, and arsenic that occurred over the course of the 10 day test due to recycle of the BATS effluent to the SW. Longer operation may require some form of metals removal or treatment.

- Once acclimated, operation of the system on a day-to-day basis requires the attention of only one operator on a part-time basis.

### 2.3.3 Slurry Bio-Reactor

Although the system did not achieve steady state, it appears that once steady state is achieved, penta removal for the liquid phase of the treated slurry would stabilize at about 97%. For the solid phase, which contains the bulk of the penta, the penta removal increased from approximately 65% to 92% but had not yet stabilized during the test. Overall penta removal reached about 96% near the end of the test, which would tend to support BioTrol's claim of 90%.

Although the data for PAHs are limited, similar behavior between solid and liquid phases is observed. Overall removal efficiencies after nine days of operation ranged between 70% and 99% for different PAHs.

Decreases in the liquid and solid phase influent penta and PAH concentrations over the course of testing suggested that some biodegradation was occurring in the holding tank, probably due to indigenous bacteria. However, it is felt that this did not have any adverse effect on test results or conclusions drawn from them since calculated removal efficiencies were based on influent and effluent concentrations at the reactor.

Copper, chromium, and arsenic concentrations are unaffected by SBR operation. At least during the nine day study, there was no evidence of bioaccumulation of these metals in the biomass.

A doubling of chloride ion concentration in the effluent compared to the influent indicates that dechlorination is occurring. The data are, however, too limited to draw any more definitive conclusions concerning mineralization.

### 2.3.4 Costs

A pilot-scale demonstration test, such as the one conducted here, is very often done before a commercial-scale remediation is attempted. The test system used by BioTrol as the basis for costs consists of a 0.25-0.50 ton/hr Soil Washer followed by a 5 gpm BioTrol Aqueous Treatment System and a 0.006 gpm Slurry Bio-Reactor. This does not mean that all three technologies must be used together. The estimated cost for such a hypothetical demonstration test at a "generic" site based on some of the costs incurred under the SITE program and on some costs provided by BioTrol would be on the order of approximately $750,000. While this is equivalent to $6000/ton for a two-week test, it is clearly impacted by such factors as lease rate, mobilization and demobilization, more intense labor requirements, and the increased sampling and analysis that would be done during a test.

Based on information provided by BioTrol, the cost for a commercial-scale Soil Washing System operating at 20 ton/hr (18.2 metric ton/hr) would be about $185/metric ton ($168 per short ton) of soil treated, including both capital cost and operating costs for the Soil Washer, three 100 gpm, 3-celled BATS units operating in parallel to treat a portion of the water being recycled, and a 23 gpm SBR consisting of three parallel trains of 3 cells to treat the contaminated fines slurry. Capital equipment is assumed to have a 10-year life with no salvage value for these calculations. The cost figure also includes the cost to incinerate the relatively small masses of contaminated coarse and fine oversized material at a cost of about $1,200/short ton. Although the mass to be incinerated is small, the impact of the cost of incineration is large. Approximately 75% of the total BSWS cost is attributable to incineration of the coarse and fine oversize material.

## SECTION 3

## PROCESS DESCRIPTION

### 3.1 PRETREATMENT AND PROCESSING REQUIREMENTS

#### 3.1.1 Soil Excavation and Preparation

Prior to the SW tests, soil was excavated from two areas at the MacGillis & Gibbs site. In the case of the Low Penta soil, it was necessary to mix the soil that had been originally selected with another soil previously excavated by BioTrol to obtain the approximate concentration desired. The soils were screened with a 3/8 inch vibrating screen to remove large particles and debris. After screening, the soils were thoroughly mixed and formed into two rectangular piles, which were covered with tarpaulins to await the start of the tests. The results of the analyses of the two piles of soil are presented in Section 4.

#### 3.1.2 Process Water

Process water generated from the SW tests was pumped into storage tanks to await treatment in the BATS. It was then pumped directly to the BATS without any pretreatment. It was evident that some settling of suspended particles was occurring in the storage tanks but this was not considered a pretreatment step. At the end of the demonstration, remaining process water was treated in the BATS and polished with granular activated carbon before it was discharged to the Minneapolis POTW.

Additional water was provided to the SW as needed to maintain the approximate ratio of 5 kg water/kg soil, either from municipal water or from that produced by the dewatering of fines.

#### 3.1.3 Slurry for SBR

The fine particle slurry for the SBR test consisted of the fines segregated in the Soil Washer dispersed in process water. It was collected from the output of the Soil Washer over a 30 hour period during the High Penta SW test and stored in a tank prior to the start of the SBR test. The contents of this storage tank were mixed by recycling a stream with a pump to keep the particles in suspension.

## 3.2 PROCESS DESCRIPTION

### 3.2.1 Introduction

Prior tests conducted by BioTrol indicated that most of the contaminants are associated with the fine particle fraction (less than 0.075 mm) of a bulk soil. Separation of the fines fraction concentrates the contaminants into a small portion of the original soil, which greatly reduces the amount of material requiring disposal or subsequent treatment.

The SW separates slightly contaminated coarser particles from heavily contaminated fine particles and, at this site, contaminated (woody) debris. The fine particles are treated in the SBR, which reduces contaminant concentration via biological destruction. The process water used in the SW is treated in the BATS prior to discharge or recycle. The actual arrangement and operation of the individual technologies will depend on site characteristics and the contaminants present. All three technologies can operate in an integrated, continuous feed mode.

### 3.2.2 Soil Washer

The SW is an intensive, countercurrent scrubbing system designed to treat excavated, contaminated soils. A generalized process flow diagram is shown in Figure 3-1. The SW is built on a 42 foot long, semi-trailer with drop-down sides using pilot-scale mineral processing equipment. Included on the trailer are a multi-component feed system, a mixing trommel, vibrating screens, froth flotation cells, attrition machines, hydrocyclones, spiral classifiers, and dewatering equipment. Four 8,000-gallon storage tanks (not trailer-mounted) provide capacity for process water inputs and outputs. The utility requirements for the SW unit are only a 440-volt, 3-phase power supply of 350 amps and a water supply of 10 gallons per minute.

Following excavation, large debris is removed from the soil by a vibrating screen. The screened soil is fed via conveyor to a mixing trommel where it is mixed with water to form a slurry. The feed rate of contaminated soil is maintained by an automatic feed-back control system which adjusts the feed rate from the conveyor belt to the mixing trommel. Overall water use is about 5 kg/kg soil (~1200 gal/ton). The water flows are measured by tank height gauges and rotameters. The slurry flows from the mixing trommel across another, finer vibrating screen where coarse oversize (CO) material is removed. The oversize product is stored in drums for disposal. The undersize material passing through this screen is fed to a flotation unit where hydrophobic constituents are removed in a froth phase. The underflow from the flotation unit then enters an intensive, multi-stage, countercurrent scrubbing circuit consisting of attrition and classification equipment. The intense scrubbing action of the attrition equipment disintegrates soil agglomerates and separates adhering fines from the coarser particles. Abrasion between the coarser particles provides additional cleaning of their surfaces. The classification equipment separates the fines from the coarse soil particles.

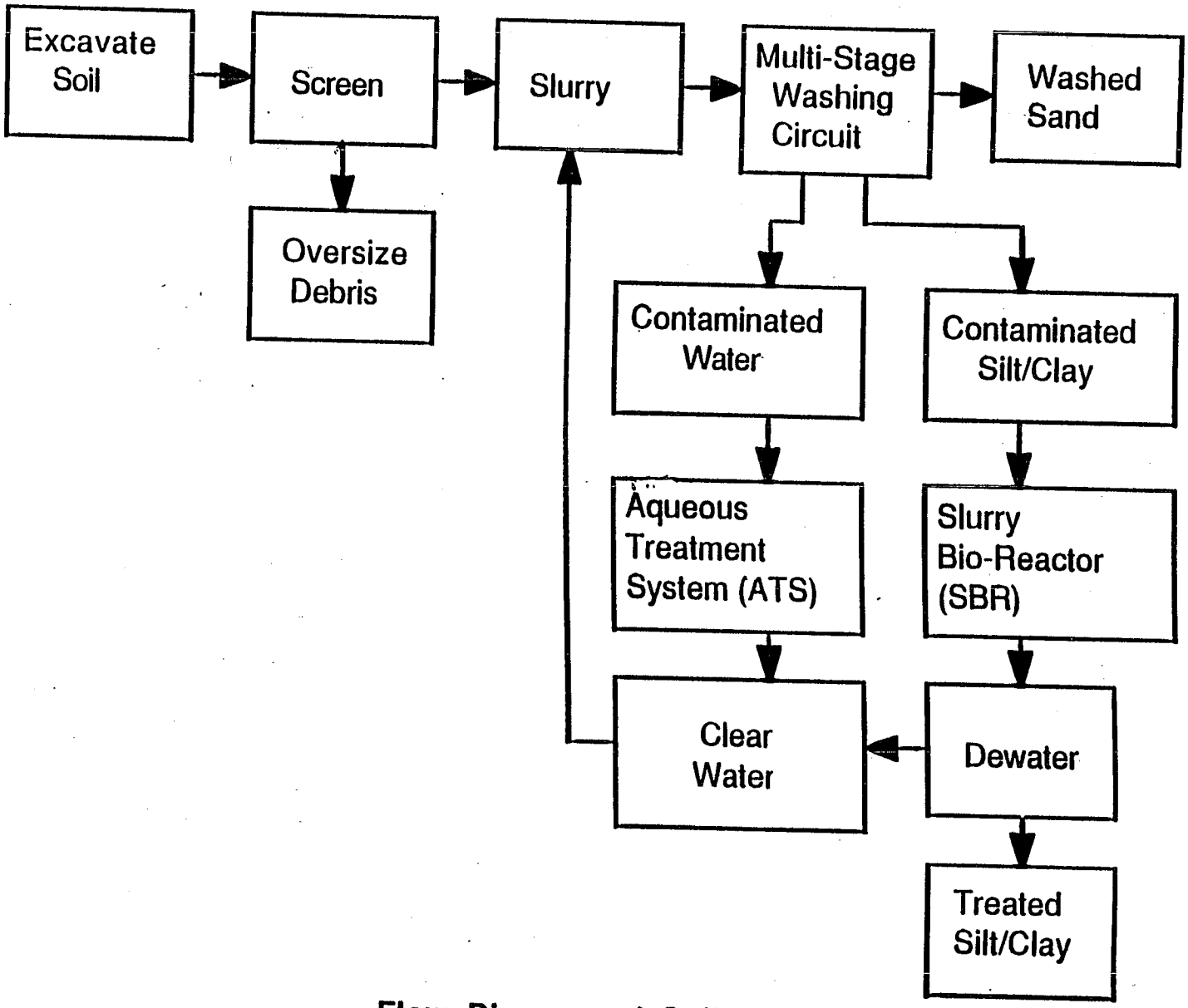


FIGURE 3-1. **Flow Diagram of Soil Washer (SW)**

The fine silt, clay, and woody matter retain considerable amounts of contaminants, even after undergoing intensive attrition scrubbing. The fine soil particles, suspended in the process water from the scrubbing circuit, are fed to a thickening operation along with the froth from the flotation unit. Just before thickening, an aqueous solution of a polymeric flocculating agent is added to assist settling and separation of the solids from the process water. The thickened solids (underflow) are then sent to the SBR for treatment as in this study (Section 3.3.3) or are dewatered using a horizontal centrifuge to form a fine particle cake (FPC) which is drummed for disposal. The FPC contains most of the contaminants from the feed soil and requires further treatment. The water removed during thickening and dewatering processes also contains significant contamination and is recirculated to the SW, eventually going to the BATS for treatment.

### 3.2.3 BioTrol Aqueous Treatment System

The BioTrol Aqueous Treatment System (BATS) is a multi-cell, submerged, packed-bed reactor where penta- and PAH-contaminated process water from the SW is biologically degraded.

The BATS used in the demonstration is a mobile, trailer-mounted unit with a nominal 10 gpm hydraulic capacity. The 20 ft x 8 ft x 8 ft enclosed trailer requires only a base capable of supporting 5 tons. Influent (process wastewater) and treated effluent are stored in 8,000 gallon carbon steel storage tanks. The utility requirement for the BATS is a 480-Volt AC, three-phase power source.

The process flow diagram is shown in Figure 3-2. After acclimation of the biological growth, including the penta-specific Flavobacterium (1 - 2 weeks), incoming wastewater is pumped on a time cycle to the 100 gallon tempering tank inside the BATS trailer (Figure 3.3).

In the tempering tank, the pH of the contaminated water is adjusted to approximately 7.3 by the addition of caustic or acid in response to on-line pH instrumentation and a concentrate of inorganic nutrients (trisodium phosphate and urea) is metered into the water at a predetermined rate to provide the needed nutrients. The nutrient concentrate is prepared on a semi-weekly basis and stored in a 50 gallon nutrient tank located inside the BATS trailer.

From the tempering tank the stream passes through a heat exchanger where the water temperature is raised to 21°C (70°F), using an auxiliary heater if necessary.

The stream is then pumped to the base of the first of three cells in the BATS reactor by passing under an influent baffle (Figure 3-4). Each of the three cells is filled with a corrugated polyvinyl chloride (PVC) media which serves as the support for microbial attachment. With the PVC media in place, each cell can hold approximately 150 gallons. A positive displacement blower supplies air to a sparger tube system mounted beneath the packing support grid of each cell. The wastewater stream flows upward from the base of each cell and contacts the fixed-film microbes. At the top of a cell, the wastewater spills over a weir into a

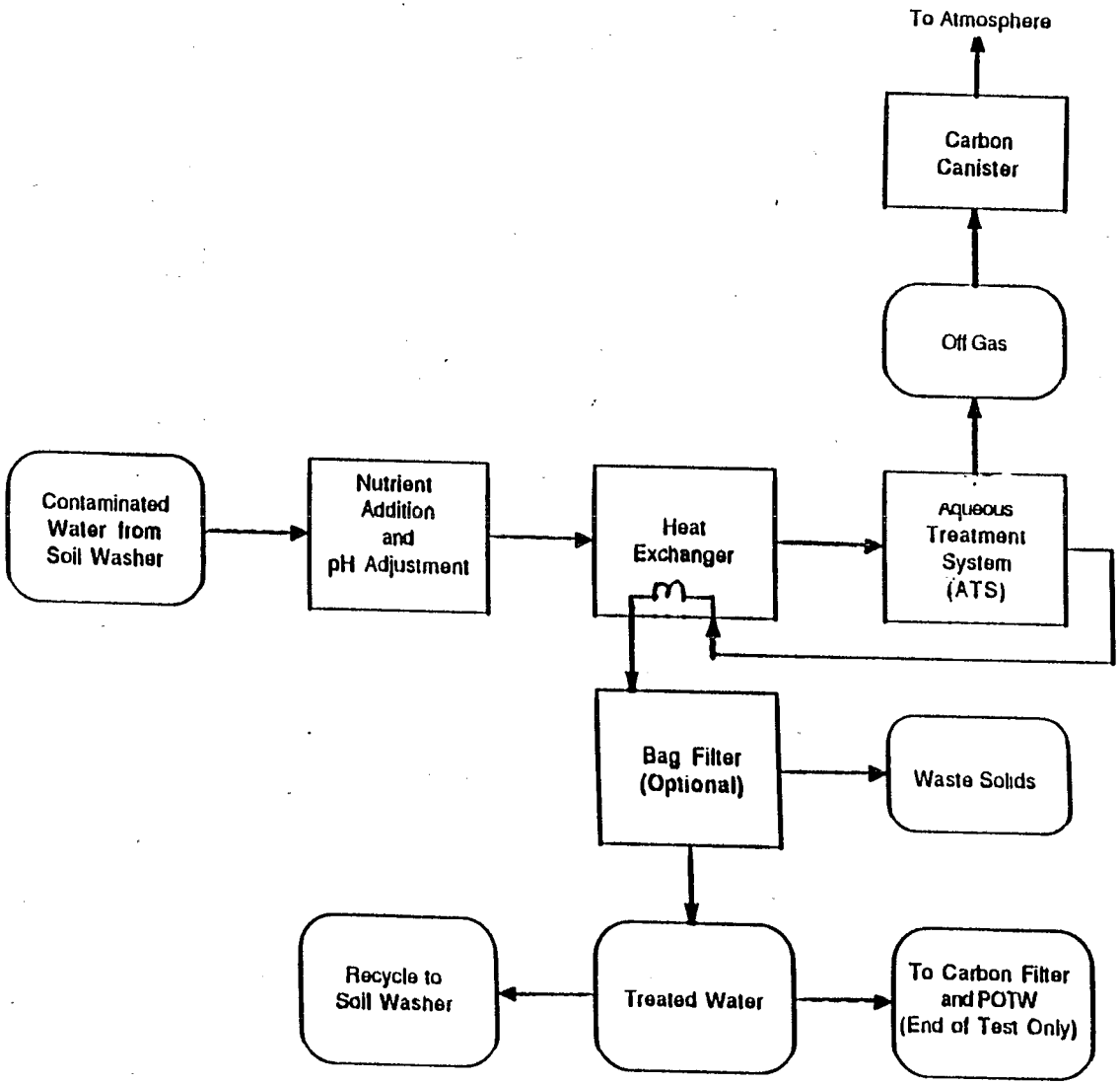


**FIGURE 3-2. Flow Diagram of BioTrol Aqueous Treatment System (BATS)**

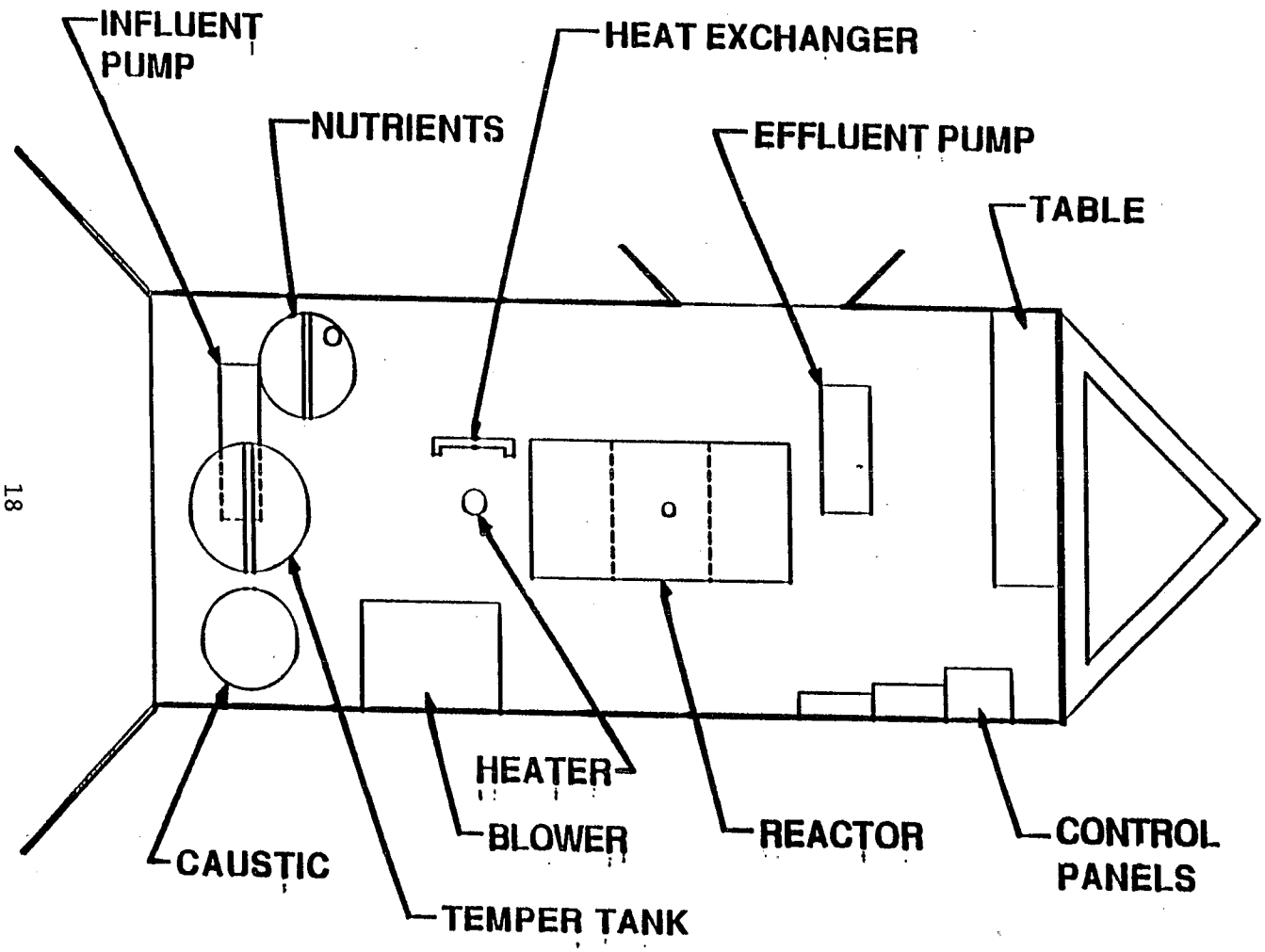


FIGURE 3-3. BIOTROL, INC. MOBILE AQUEOUS TREATMENT SYSTEM

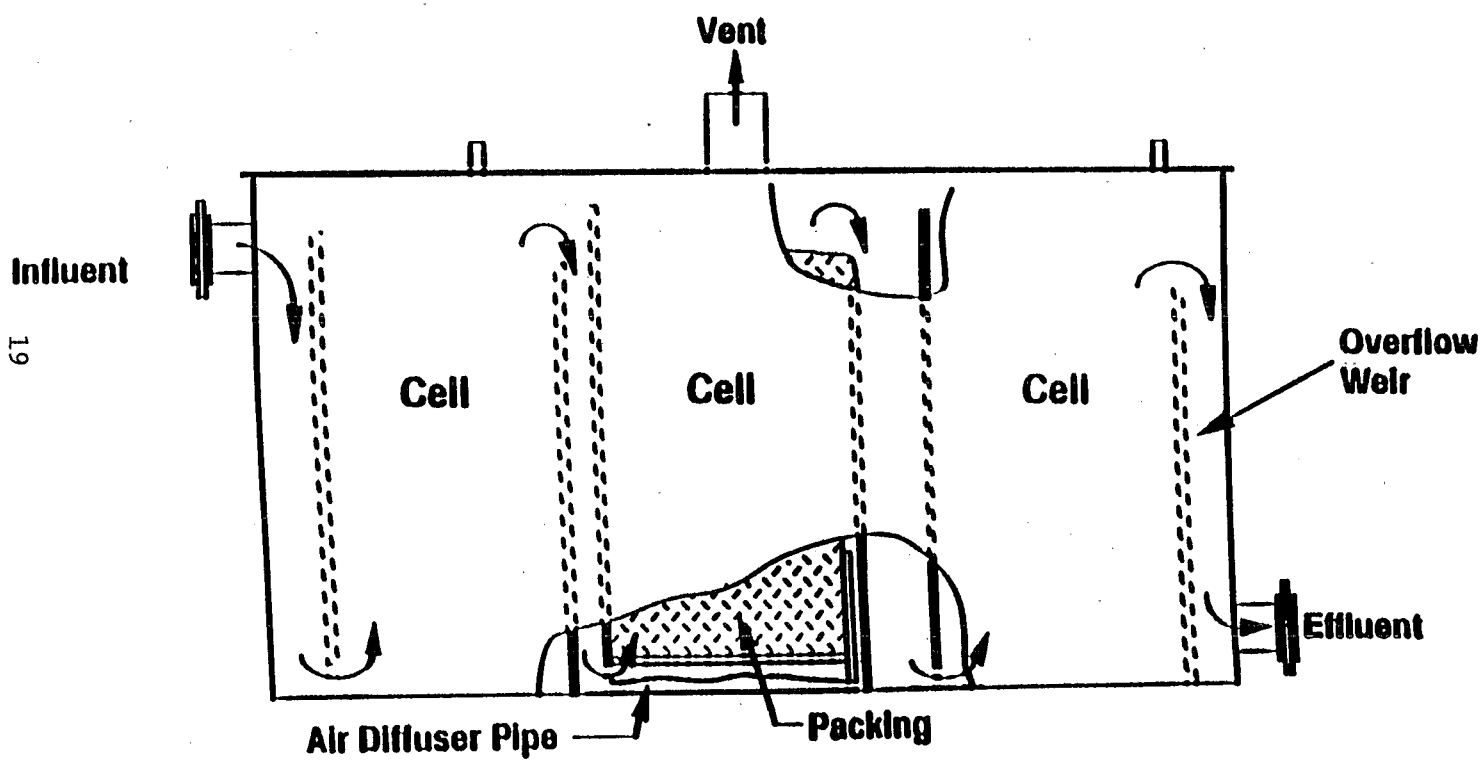


FIGURE 3-4. SCHEMATIC OF BIOREACTOR

narrow slot that directs the flow to the base of the next cell for further treatment.

The lid over the BATS reactor is fitted with a 4-inch diameter piece of flexible tubing to capture and funnel the offgases from the BATS through a carbon adsorption canister that was added for the demonstration study. After passing through the carbon canister, the air is exhausted to the atmosphere.

When the treated water exits the third cell of the BATS reactor, it passes through the heat exchanger and any heat added during its pass through the BATS reactor is returned to the influent. The treated water leaves the BATS trailer and is pumped to a holding tank for recycle in the SW. As an added precaution, a bag filter was added to remove sloughed biomass before the effluent was discharged to the POTW at the end of test. If necessary, carbon adsorption can be used for polishing prior to discharge.

### 3.2.4 Slurry Bio-Reactor

The Slurry Bio-Reactor (SBR) is a microbiological system for degrading penta and PAHs adsorbed in or absorbed on the surface of woody material, silt, and clay particles (Figure 3-5). The bacterial population consists of indigenous bacteria supplemented by a penta-specific *Flavobacterium*. The units used in the demonstration study were designed by and purchased from EIMCO, Inc.

The EIMCO SBR consists of three upright, continuously-stirred, stainless steel reactors arranged in series, each with a capacity of 60 liters (Figure 3-6). The three reactors are arranged in a cascading system, permitting continuous feed and overflow by gravity at a rate of about 24 ml/min (0.006 gpm). The slurry of clay and silt fines enters the first reactor where easily degraded contaminants are consumed by the pre-inoculated and acclimated microbial population. As the slurry flows to each successive tank, the more refractory contaminants are eventually broken down. Each reactor contains a modified slurry agitator incorporating an airlift pump which returns settled solids that have been raked to the center back to the top and redistributes them. Flexible membrane diffusers mounted on stainless steel rotating rake arms provide fine bubble aeration and turbulence for mixing. The membrane diffusers are a non-clog type constructed of an elastomeric material which is resistant to the contaminants. In this manner, mixing is maintained while shear forces are kept low to allow microorganisms to adhere and grow on the surface of the particles in the slurry. The reactors are sealed and all gases are vented through an activated carbon canister as a precaution to prevent emission of organic compounds into the environment.

Five variables must be controlled for proper operation of the Slurry Bio-Reactor system. They are: the influent flow rate, temperature, dissolved oxygen concentration, gas flow rate, and rake arm speed. The goal is to operate the reactor system at steady state, which minimizes operator attention and maximizes the biological degradation rate. The influent flow rate is controlled by a variable speed peristaltic pump. The system is equipped with heaters and a thermostat. The dissolved oxygen concentration, a function of the gas flow rate, the oxygen concentration in the gas, and the rate of uptake by the

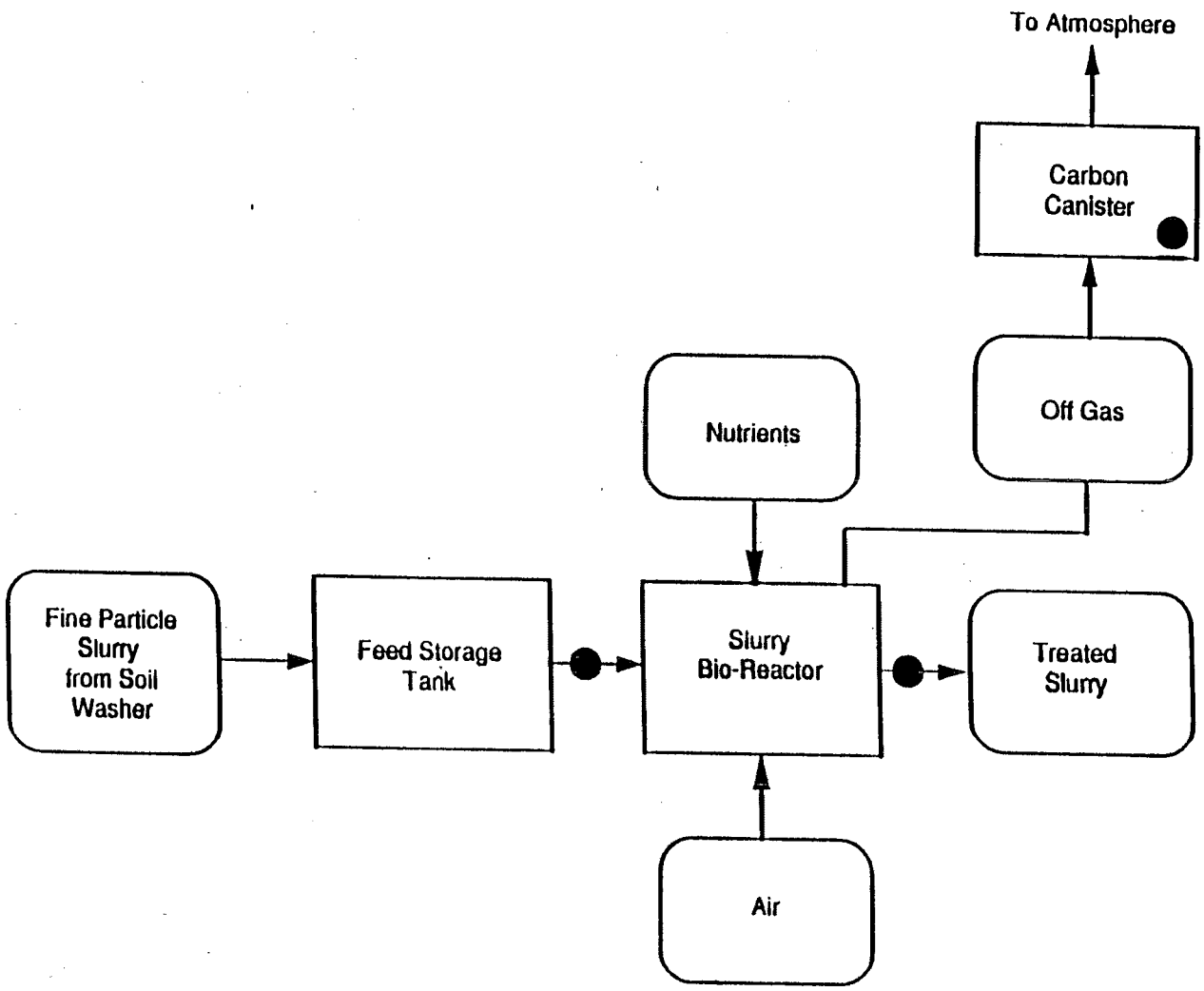


FIGURE 3-5. Flow Diagram of the Slurry Bio-Reactor (SBR) with Sample Points

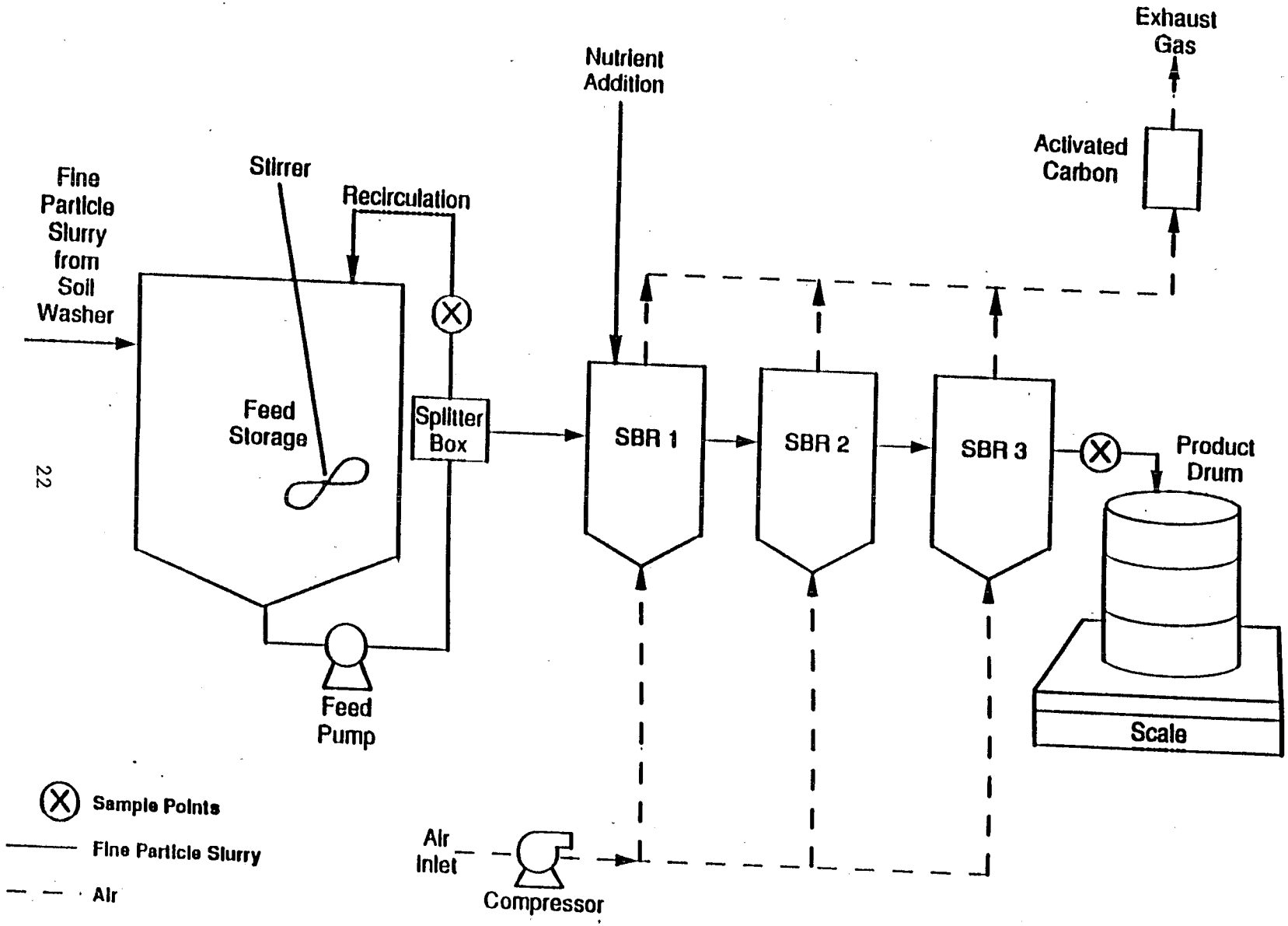


FIGURE 3-6. Slurry Bio-Reactor Process Flow Diagram

microorganisms, is controlled by the air flow rate and is measured using a dissolved oxygen probe. All gas flow rates are monitored by rotameters. The rake arm speed is controlled by a variable speed drive.

The only utility requirement for the SBR is a 110 volt, single phase power source.

The SBR system that was tested is much smaller in hydraulic capacity than the SW and BATS systems. Consequently, rather than feed a portion of the fine particle slurry to the SBR from the SW on a continuous basis, the fine particle slurry was diverted from the SW into a 500 gallon storage tank for one day during the middle of the High Penta soil washing test. The storage tank was equipped with a circulating stream to agitate the slurry and maintain particles in suspension.

## 3.3 ANCILLARY POLLUTION CONTROL EQUIPMENT

To prevent accidental spills and splashing from contaminating the demonstration area grounds, impermeable liners were installed underneath the feed hopper, the feed conveyor, the SW trailer, and the SBR. The liners were bordered by absorbent socks to control potential runoff. To minimize runoff due to weather conditions, process areas were covered by temporary roof structures or tarpaulins, as necessary. These areas included the feed hopper, the feed conveyor-belt, the SBR, and the SBR storage tanks.

The air emissions from the BATS and the SBR reactors were passed through carbon adsorption canisters to assure that no hazardous constituents were being released. For this demonstration, carbon was used even though air monitoring conducted during the previous BATS demonstration indicated that this was not necessary. Sloughed biomass from the BATS was captured by a bag filter and collected in 55-gallon drums for disposal only at the end of the test when effluent was discharging to the local POTW. At other times the effluent was recycled to the SW without filtration.

## 3.4 WASTE REMOVAL AND SITE CLOSURE

Process wastes generated during the demonstration and drummed for subsequent disposal included Coarse Oversize, Fine Oversize, Fine Particle Cake, bag filters, and carbon canisters. Non-process wastes generated during pre-demonstration and demonstration phases of the study included health and safety disposables (e.g., Tyvek® suits, gloves, etc.) and water and solvents from the decontamination of sampling equipment. At this time, all of these materials are containerized and awaiting disposal at an off-site facility meeting state and Federal regulations.

## SECTION 4

## THE BIOTROL FIELD DEMONSTRATION

### 4.1 BACKGROUND

#### 4.1.1 Technology Description

The pilot-scale BSWS treatment train, shown schematically in Figure 4-1 as configured for this demonstration, consists of three technologies which are designed to work in an integrated fashion to treat contaminated soils. The technologies are:

- Soil Washer (SW)
- BioTrol Aqueous Treatment System (BATS)
- Slurry Bio-Reactor (SBR).

The SW is an intensive countercurrent scrubbing system which separates slightly contaminated coarse soil particles from heavily contaminated fine particles. The process water used in the SW is treated in the BATS prior to discharge or recycle. The BATS, a multi-cell, submerged, packed-bed biological reactor, removes contaminants from the process water. The contaminated fine clay and silt particles are treated in the SBR. The SBR consists of three cascading aerated reactors which provide an aerobic environment for microbial growth. Section 3 provided descriptions of the three treatment technologies. As noted earlier, the SBR is significantly smaller in hydraulic capacity than the SW or BATS.

#### 4.1.2 Site Description

The SITE demonstration of this configuration of the BioTrol Soil Washing System was conducted at the MacGillis & Gibbs Superfund site located 7 miles north of Minneapolis, at 440 5th Avenue, NW, New Brighton, Minnesota. The 24 acre site is bounded by 5th Avenue NW to the east, 1st Street to the south, the Minnesota Transfer Railroad and Bell Lumber and Pole Company parcel No. 2 properties to the west, and private residential land to the north (Figure 1-1). The surrounding area consists of wetlands to the east, west, and north and lakes both to the north and south of the site. Results of a previous Remedial Investigation Report indicate that the soil is part of the New Brighton Formation and is composed of a silty sand which is interlaid with organic matter in some areas of the site and underlain by localized silt lenses and clay. Results of a previous hydrogeological investigation indicate that an unconfined surficial aquifer which is recharged through the infiltration of precipitation is continuous across the site. Groundwater depths range from 3.2 to 13.5 feet (Twin Cities Testing, 1986).

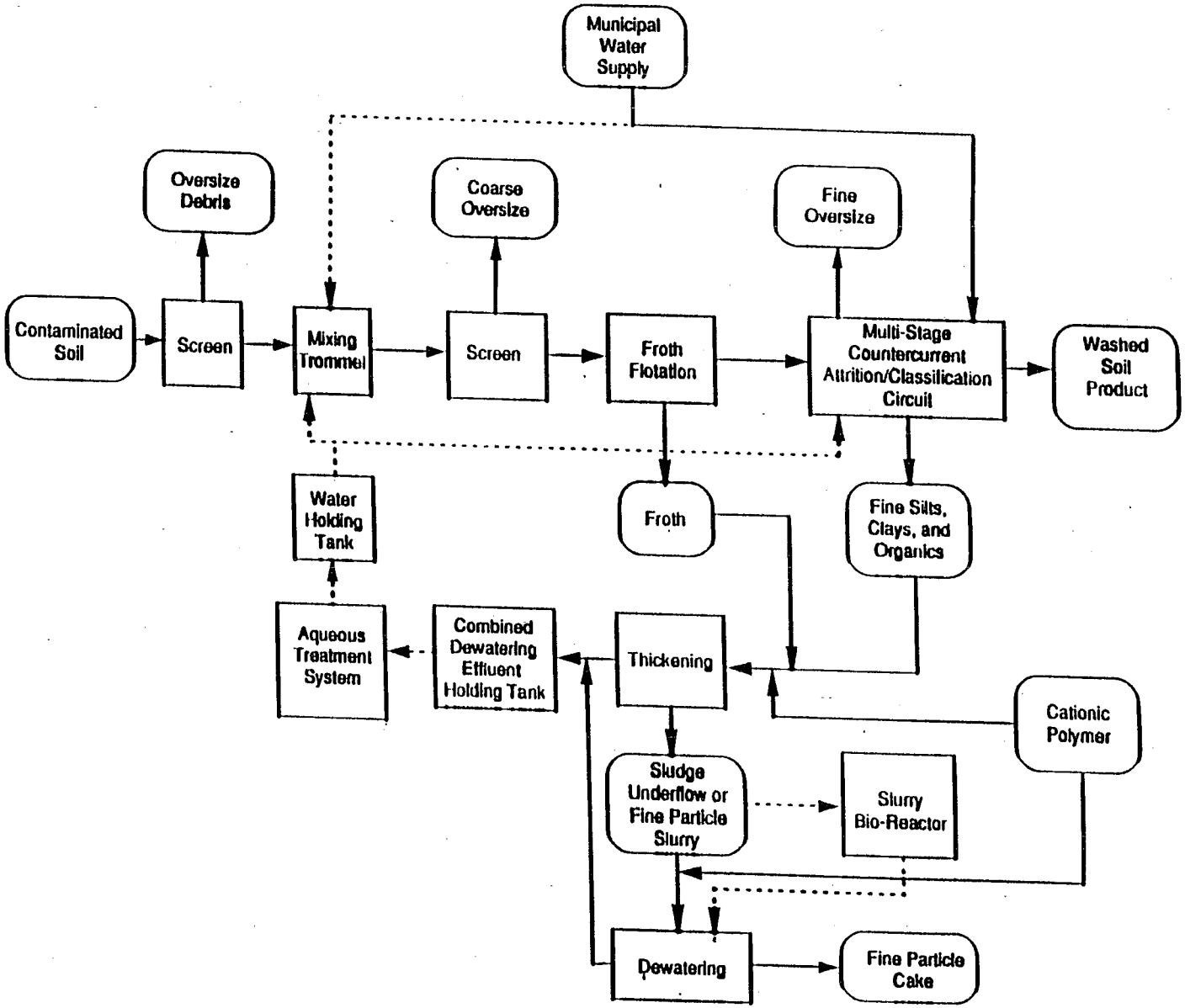


FIGURE 4-1. Flow Diagram of the Soil Washer System

The MacGillis & Gibbs Company has been operating a wood treatment facility on this site since approximately 1920. Contaminants present at the site include creosote, which is a coal-tar distillate, pentachlorophenol (penta), and chromium, copper, and arsenic. Creosote was used as a wood preservative from the time operations began until approximately 1950. During the late 1940s, the MacGillis & Gibbs Company began using a 5 percent mixture of penta in fuel oil. Penta was phased out in the mid-1970s and replaced by another wood preservative, chromated copper arsenate (CCA).

The MacGillis & Gibbs site was placed on the National Priorities List (NPL) in conjunction with the neighboring Bell Lumber and Pole site in September 1983 because of surface and groundwater contamination. As part of the NPL listing process, each potential Superfund site is evaluated using the Hazard Ranking System (HRS). Each site is given an HRS score, which represents a composite of values assigned from a standard set of factors related to risks from potential or actual migration of hazardous substances through groundwater, surface water, and air. The site, ranked 201 out of 799 on the NPL in June 1987, is one of 54 wood preserving sites currently listed.

### 4.1.3 Demonstration Test Plan

The Demonstration Test Plan delineates personnel schedules, procedures, and steps involved in the collection of data and evaluation of the BioTrol technologies. The data collected from the SITE demonstration test will be used by potential users of the technology to make sound decisions as to the applicability of the process. Since the data collected from the demonstration test may be used to "prove" a technology, the procedures used to collect and analyze samples must be thoroughly planned and must comply with guidelines set forth by RREL's Category II Quality Assurance Project Plans (QAPjP). Data quality objectives (DQO) were explicitly defined in the QAPjP, which is a supplement to the Demonstration Test Plan. The Demonstration Test Plan along with the QAPjP ensure that all the necessary information is collected to evaluate the technology and that data generated and collected throughout the demonstration are of a quality sufficient to support sound scientific conclusions. This report includes a Quality Assurance Section that presents an assessment of data quality and describes corrective actions taken during the course of the demonstration. The QA Section summarizes QAPjP specifications for collected data and presents an overall evaluation of the data quality in terms of the QAPjP requirements.

## 4.2 DEMONSTRATION PROCEDURES

### 4.2.1 Site Preparation

BioTrol had been conducting tests of their technology at the site over the past year; therefore, the three technologies along with the 4 water storage tanks used to control water flow through the system were already on-site. The concrete pads needed to support the SBR and the drums for wastes also were already in place at the MacGillis & Gibbs site and did not need to be installed.

Prior to the start of the site demonstration, all the necessary equipment needed to evaluate the technologies was mobilized and installed on-site. This

included testing equipment, personnel support facilities, and residuals handling equipment. Soils for the demonstration tests were excavated from two areas of the site and placed in two separate, covered piles.

### 4.2.2 Field Operations

#### 4.2.2.1 Soil Washer Demonstration

The Soil Washer Demonstration consisted of two tests: one with soil containing the low penta concentration (130 ppm) and one with the high penta concentration (680 ppm). As noted earlier, these tests and any derivative studies or analyses will be referred to as Low Penta and High Penta. The Low Penta test began on September 25, 1989 at 12:37 after Feed Soil (FS) had circulated through the Soil Washer for approximately one hour. Sampling was initiated two hours later at 14:37. Eight composite samples were collected over a period of 50 hours. The Low Penta SW test concluded at 15:07 on September 27, 1989. The final composite sample was collected at 15:07 that day. A total of about 11,000 kg was treated, or an average of 220 kg/hr.

The High Penta test began on September 29, 1989 at 23:48, again after Feed Soil had circulated through the Soil Washer for approximately one hour. Sampling was initiated two hours later at 01:48 on September 30, 1989. Eighteen composite samples were collected over a period of 150 hours. On October 1, 1989 at 23:40 sample and data collection was temporarily suspended (as scheduled) while Fine Particle Slurry (the precursor to the Fine Particle Cake) was diverted from the Soil Washer's centrifuge to a holding tank for use as feed in the Slurry Bio-Reactor evaluation. Sampling of the High Penta test resumed thirty hours later at 08:00 on October 3, 1989 and concluded at 03:44 on October 6, 1989. The final composite sample was collected at 03:44 that day. A total of 18,000 kg of "as is" soil was treated.

#### 4.2.2.2 BioTrol Aqueous Treatment System Test

The BATS study also consisted of two tests and was integrated with the SW operations. The first test began on September 26, 1989 at 13:01 when the feed to the BATS was switched from groundwater to SW process water generated during the Low Penta Soil Washer test. Sampling was initiated at 18:55 on the same day. Fourteen 6-hour composite samples were collected over a period of approximately 3 1/2 days and the test was completed on September 30, 1989 at 10:48.

The second test began when the BATS feed was switched to SW process water generated during the High Penta Soil Washer test at 10:48 on September 30, 1989. Sampling was initiated at 12:57 on the same day. Twenty-three 6-hour composite samples were collected over a period of approximately 6 1/2 days. The test was completed on October 6, 1989 at 16:15.

#### 4.2.2.3 Slurry Bio-Reactor Test

The SBR system that was tested is smaller in hydraulic capacity than the SW and BATS and could not be integrated. One test was conducted of the SBR system. Rather than feed a portion of the fine particle slurry to the SBR from the SW on a continuous basis, which would have been very impractical, the fine particle slurry was diverted from the SW into a 500 gallon storage tank for one day during the middle of the High Penta soil washing test. The storage tank was equipped with a pump that circulated a stream to agitate the slurry and keep particles in suspension. The test began on October 16, 1989 at 14:08 when the first grab sample of the first composite was collected. Fourteen composite samples were collected over a period of two weeks. The test ended on October 31, 1989 at 10:45.

### 4.2.3 Field Measurements

#### 4.2.3.1 Soil Washer

Field measurements were collected at various intervals over the course of the Soil Washer tests. The masses of Coarse Oversize (CO), Fine Oversize (FO), Fine Particle Cake (FPC), and Washed Soil (WS) output streams were determined by weighing drums of each stream as filled, rather than at specified time intervals. Individual output stream flow rates dictated the frequency and number of measurements of each. Every two hours, flow rates of Combined Dewatering Effluent (CDE), Municipal Water (MW), BATS Treated Water (High Penta Soil Washer test only) and Cationic Polymer Solution (thickener) were measured by either recording the depth of liquid in the respective tank or by recording a rotameter reading. Feed Soil flow rate was measured every two hours by recording the feed system's total mass. Every two hours, the air temperature was measured using a standard mercury thermometer. Every eight hours, pH measurements of Combined Dewatering Effluent were made from grab samples and power readings were recorded from a standard domestic electric power meter. Table 4-1 summarizes the field measurements that were obtained.

#### 4.2.3.2 BioTrol Aqueous Treatment System

Field measurements were made at various intervals and frequencies over the course of the BATS tests, as noted in Table 4-2. Influent, effluent, and nutrient flow rates were determined every two hours by recording the depth of liquid in the respective tank and calculating the changes in volume. Every eight hours, pH and temperature were measured on grab samples taken at "T" joints in the influent and effluent lines of the system. Power readings were recorded every eight hours from a standard domestic electric power meter. The weight of the carbon adsorption residue was measured using a direct-read floor scale.

#### 4.2.3.3 Slurry Bio-Reactor

Table 4-3 lists the field measurements made to characterize the process. A splitter box diverted flow from the recycle stream of the storage tank to the SBR feed for six seconds out of every minute. The influent flow rate measurement and all analytical samples were taken from the recycle stream to take advantage

## TABLE 4-1. SOIL WASHER FIELD MEASUREMENTS

| Measurement | Frequency | Device | Units |
|---|---|---|---|
| Flow Measurements: | | | |
| Coarse Oversize (CO) | Each Filled Drum | Platform Balance | Pounds |
| Fine Particle Cake (FPC) | Each Filled Drum | Platform Balance | Pounds |
| Fine Oversize (FO) | Each Filled Drum | Platform Balance | Pounds |
| Washed Soil (WS) | Each Filled Drum | Platform Balance | Pounds |
| Feed Soil (FS) | 2 Hours | Totalizer | Pounds |
| Combined Dewatering Effluent (CDE) | 2 Hours | Tank Depth Gage | Inches |
| Municipal Water | 2 Hours | Rotameter | Gallons/minute |
| BATS Treated Water (High Soil Test Only) | 2 Hours | Tank Depth Gage | Inches |
| Cationic Polymer | 2 Hours | Rotameter | Gallons/hour |
| Other Measurements: | | | |
| Air Temperature | 2 Hours | Mercury Thermometer | Celsius |
| CDE pH | 8 Hours | pH Meter | pH Units |
| Power | 8 Hours | Power Meter | kW-hrs |

A:\TABLE4-1.WK1

TABLE 4-2. BIOTROL AQUEOUS TREATMENT SYSTEM FIELD MEASUREMENTS

| Measurement | Frequency | Measurement Device |
|---|---|---|
| Influent Flow Rate | 2 hours | Level indicator |
| Effluent Flow Rate | 2 hours | Level indicator |
| Nutrient Flow Rate | 2 hours | Tape Measure |
| pH Chemicals Flow Rate | Beginning & end of the test | Direct-read floor scale |
| Influent pH | 8 hours | Hand-held pH meter |
| Effluent pH | 8 hours | Hand-held pH meter |
| Influent Temperature | 8 hours | Immersible thermometer |
| Effluent Temperature | 8 hours | Immersible thermometer |
| Power | 8 hours | Standard domestic electric power meter |
| Carbon Residue Weight | At the end of the test | Direct-read floor scale |

file: TAB4-2.WK1

## TABLE 4–3. SLURRY BIO–REACTOR FIELD MEASUREMENTS

| Measurement | Frequency | Measurement Device |
|---|---|---|
| Influent Flow Rate | 12 hours | 1000 ml graduated cylinder and stopwatch |
| Influent Density | 12 hours | 1000 ml graduated cylinder and analytical balance |
| Effluent Density | 12 hours | 1000 ml graduated cylinder and analytical balance |
| Effluent Total Mass | 60 min. | Direct–read floor scale |
| Influent pH | 12 hours | Hand–held pH meter |
| Effluent pH | 12 hours | Hand–held pH meter |
| Power | 12 hours | Standard domestic electric power meter |
| Carbon Residue Weight | At the end of the test | Direct–read floor scale |

file: TAB4–3.WK1
date: March 2, 1991

of its higher flow rate. The influent density was measured at this point twice a day. The effluent density was also measured twice a day, corresponding in time to the influent density measurement. The effluent mass was measured by noting the weight of a drum on a scale. Six grab samples taken at four hour intervals were composited once every twenty-four hours for chemical analyses.

### 4.2.4 Sampling and Analysis

Sampling and analysis of all process streams was conducted according to the sampling and analysis plan outlined in the Demonstration Test Plan. Pentachlorophenol (penta) and Polynuclear Aromatic Hydrocarbons (PAHs) were defined as "critical" parameters.

The following were considered as "secondary critical" parameters:

- Copper, Chromium, and Arsenic (CCA)
- Polychlorinated Dibenzodioxins/Dibenzofurans (PCDDs/PCDFs)
- Total Residue (TR).

These contaminants were deemed critical in an evaluation of the technology because the BSWS was designed to treat penta and PAHs; the metals were expected to be present in the feed soils based on facility history; the presence or absence of PCDDs/PCDFs would be a determining factor in selecting disposal options; and TR was necessary to perform mass balance/material inventory calculations. In addition to the critical contaminants, selected samples also were analyzed for the following:

- Total Recoverable Petroleum Hydrocarbons (TRPH)
- Chemical Oxygen Demand (COD)
- Other Metals (Ba,Cd,Pb,Hg,Se,Ag) (MTLS)
- EP Toxicity (EP Tox)
- Toxicity Characteristic Leaching Procedure (TCLP)
- Total Organic Carbon (TOC)
- Chloride Ion Concentration (Cl)
- Total Organic Halides (TOX)
- Cation Exchange Capacity (CEC)
- Particle Size Analysis and Chemical Analysis of Particle Size Fractions (PS).

These measurements were made for process characterization, soil characterization, and waste disposal information. Table 4-4 lists the analytical methods selected for each of these analyses. The results of all testing are presented later in Section 4.4.

#### 4.2.4.1 Predemonstration Sampling and Analysis

Soil samples from the low penta concentration soil pile and the high penta concentration soil pile were collected on September 25, 1989 (after removal of large sized debris) prior to the start of the demonstration test using a fixed-grid sampling pattern. A full-depth core sample was obtained from each of 8 locations on the soil pile with Low Penta and 12 locations on the High Penta

TABLE 4-4. ANALYTICAL METHODS USED DURING THE BSWS SITE DEMONSTRATION

| Analyte | Sample Preparation Aqueous/Soil | Sample Analysis Aqueous/Soil | Source Document |
|---|---|---|---|
| Penta and PAHs | 3520/3550 | 8270/8270 | SW-846 |
| PCDDs and PCDFs | 8280/8280 | 8280/8280 | SW-846 |
| Metals (Ba,Cd,Cr,Cu,Pb) | 3010/3050 | 6010/6010 | SW-846 |
| Arsenic | 7060/3050 | 7060/6010 | SW-846 |
| Mercury | 7470/7471 | 7470/7471 | SW-846 |
| Selenium | 7740/3050 | 7740/6010 | SW-846 |
| Silver | 7760/3050 | 7760/6010 | SW-846 |
| Total Residue | ---/--- | 160.3/3550 | EPA-600 |
| Total Recoverable Petroleum Hydrocarbons | 418.1/418.1 | 418.1/418.1 | EPA-600 |
| Chemical Oxygen Demand | ---/--- | 410.1/--- | EPA-600 |
| EP Toxicity | 1310/1310 | ---/--- | SW-846 |
| Toxicity Characteristic Leaching Procedure | ---/1311<br>---/3510 | ---/8270<br>---/8280 | 40 CFR 268, App. I |
| Total Organic Carbon | ---/--- | ---/9060 | SW-846 |
| Chloride Ion | 300/--- | 300/--- | EPA-600 |
| Total Organic Halide | 9020/--- | 9020/--- | SW-846 |
| Cation Exchange Capacity | ---/--- | ---/9081 | SW-846 |
| Particle Size Analysis and Chemical Analysis of Particle Size Fractions | ---/D421 | ---/D422 | SW-846 |

Source Documents:

ASTM Standard Methods D421-58(Reapproved 1978) and D422-63(Reapproved 1972), American Society for Testing and Materials Annual Book of ASTM Standards, Vol. 4.08.

40 CFR 268 Federal Register, Vol. 51, No. 114, June 13, 1986, pp. 21685-21693.

EPA-600/4-79/020 Methods for Chemical Analysis of Water and Wastes (EPA, 3/1979).

SW-846 Test Methods for Evaluation Solid Waste (EPA, 11/1986).

soil pile. Each of the core samples was analyzed as a grab sample for penta, PAHs, and TR. A composite sample for each pile (made up of the individual core samples) was analyzed for penta, PAHs, CCA, MTLS, TR, EP Tox, TOC, TRPH, PCDDs/PCDFs, CEC, and PS. The results of these tests, presented later in Section 4.3.1 and in the Appendices, are considered representative of the piles used in the study.

In addition, samples of the Low and the High Penta soil samples were subjected to particle-size analysis and classified according to the Unified Soil Classification System (USCS). The USCS is the most universally accepted soil classification system and has been adopted by the American Society for Testing and Materials (ASTM). It is based on textural characteristics for soils with small amounts of fine particles that do not affect the behavior of the soil, such as the soil used in the BioTrol SITE Demonstration.

In the USCS, four characteristic soil fractions are used to designate the size ranges of soil particles. These four fractions are as follows:

| Fraction | Size Range |
|---|---|
| Cobbles | >76.2mm (3") |
| Gravel | 76.2mm to #4 sieve (4.75mm) |
| coarse gravel | 76.2mm to 19.05mm |
| fine gravel | 19.05mm to #4 sieve (4.75mm) |
| Sand | #4 to # 200 sieve (4.75mm to 0.075mm) |
| coarse | #4 to #10 sieve (4.75mm to 2.0mm) |
| medium | #10 to #40 sieve (2.0mm to .425mm) |
| fine | #40 to #200 sieve (.425mm to 0.075mm) |
| Fines (silts and clays) | Below #200 sieve (<0.075mm) |

After sieving, the particle-size fractions were combined into four solid fractions and one aqueous fraction and analyzed for pentachlorophenol (penta), polynuclear aromatic hydrocarbons (PAHs), and copper, chromium and arsenic (CCA). The fractions were grouped as follows for analysis:

- Material retained on the #3/8, #4, and #10 sieves
- Material retained on the #20, and #40 sieves
- Material retained on the #60, #140, and #200 sieves
- Solid material passing the #200 sieve
- Aqueous solution passing the #200 sieve.

While the data presented later in Section 4.4.2 for both the Feed Soil and the output streams give considerable insight into the weight and contaminant distribution, the reader is cautioned that these data are not directly comparable to that observed in the pilot-scale Soil Washer.

#### 4.2.4.2 Demonstration Sampling and Analysis

Since the SW is considered a continuous operation, sampling strategy involved a fixed interval sampling. Likewise, fixed interval sampling was also adopted for the BATS and SBR. The sampling schemes for the three technologies are summarized in the following paragraphs.

Soil Washer -- The sampling scheme for the SW is presented in Table 4-5. All grab samples were collected using heavy duty glass beakers. Grab samples were combined in glass composite containers kept on ice.

BioTrol Aqueous Treatment System -- The sampling scheme for the BATS is presented in Table 4-6. The BATS influent and effluent samples were collected using ISCO samplers that automatically collected 250 ml grab samples every 10 minutes and deposited them in an ice-chilled composite container. The BATS carbon canister was sampled at the end of the test by manually compositing four 750 ml grab samples of the carbon.

Slurry Bio-Reactor -- The sampling scheme for the SBR is presented in Table 4-7. The SBR influent and effluent samples were collected using heavy duty glass beakers. Composite samples of the SBR influent and effluent consisting of six grab samples taken with heavy duty glass beakers at four hour intervals were stored in glass composite containers kept on ice. At the end of the test the contents of the SBR carbon canister were split into two halves and composite samples of each half were obtained.

#### 4.2.4.3 Post-Demonstration Sampling and Analysis

Drum Sampling--The nine types of wastes generated during the demonstration were as follows:

- Fine Particle Cake/Oversize
- Coarse Oversize
- Decontamination water containing hexane
- Decontamination water containing methanol
- Combined Dewatering Effluent
- General debris
- F003-Contaminated Debris
- Acid preserved aqueous samples

Following the demonstration, samples were taken of these wastes stored in 55-gallon drums. These samples were sent to a designated waste disposal facility for treatability testing to provide proper and safe disposal of the wastes. Composite samples or grab samples were collected of each of the waste streams. Composite samples consisted of 2-3 grab samples. Liquids were sampled with lengths of glass tubing and solids were sampled with a stainless steel ladle.

Dioxin Sampling--Samples of the Washed Soil, Fine Particle Cake, Fine Oversize, Coarse Oversize, and Combined Dewatering Effluent were collected for high resolution dioxin/furan analysis by SW-846 Method 8290. Solid samples were composites and aqueous samples were grabs.

Site Area Sampling--Soil sampling of the test staging area was performed after the demonstration was completed to insure that no contamination was caused by demonstration activities. Grab samples collected at 10 different locations on-site at depths of 6" and 18" with a stainless steel hand-held bucket auger confirmed that the demonstration had not adversely affected the ground. Measurable concentrations of penta were only found in some of the 18" deep samples, probably reflecting the condition of the site.

TABLE 4-5. SOIL WASHER SAMPLES

| Sample | Matrix | Sample Type | Frequency | Analytical Parameters |
|---|---|---|---|---|
| Feed Soil | Solid | Manual Composite | 6-Hour Composite from 2-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH |
| Washed Soil | Solid | Manual Composite | 6-Hour Composite from 2-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH, EP TOX, TCLP, MTLS, PCDDs, PCDFs |
| Coarse Oversize | Solid | Manual Composite | 6-Hour Composite from 2-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH, EP TOX, TCLP, MTLS, PCDDs, PCDFs |
| Fine Oversize | Solid | Manual Composite | 6-Hour Composite from 2-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH, EP TOX, TCLP, MTLS, PCDDs, PCDFs |
| Fine Particle Cake | Solid | Manual Composite | 6-Hour Composite from 2-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH, EP TOX, TCLP, MTLS, PCDDs, PCDFs |
| Combined Dewatering Effluent | Aqueous | Manual Composite | 6-Hour Composite from 2-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH, EP TOX, TCLP, MTLS, PCDDs, PCDFs |
| BATS Recycle Water | Aqueous | Manual Composite | 12-Hour Composite from 4-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH |
| Municipal Water | Aqueous | Manual Composite | 12-Hour Composite from 4-Hourly Grabs | Penta, PAHs, CCA, TR, TOC, TRPH |
| Thickener Solution | Aqueous | Manual Grab | End of Test | Penta, PAHs |

file: 4-5.WK1
date: March 4, 1991

## Table 4–6. BIOTROL AQUEOUS TREATMENT SYSTEM SAMPLES

| Sample | Matrix | Sample type | Frequency | Analtyical Parameters |
|---|---|---|---|---|
| BATS Influent | Aqueous | Automatic Composite | 6-Hour Composite | Penta, PAHs, CCA, TR, TRPH, COD, TOX, C |
| BATS Effluent | Aqueous | Automatic Composite | 6-Hour Composite | Penta, PAHs, CCA, TR, TRPH, COD, PCDDs, PCDFs, MTLS, TOX, C |
| Carbon Canister | Solid | Manual Compoiste | End of Test | Penta, PAHs, TR, PCDDs, PCDFs |

## TABLE 4–7. SLURRY BIO–REACTOR SAMPLES

| Sample | Matrix | Sample type | Frequency | Analtyical Parameters |
|---|---|---|---|---|
| SBR Influent | Solid | Manual Composite | 24-Hour Composite from 4-Hourly Grabs | Penta, PAHs, CCA, TR TRPH, COD, TOX, CL |
| SBR Effluent | Solid | Manual Composite | 24-Hour Composite from 4-Hourly Grabs | Penta, PAHs, CCA, TR TRPH, COD, PCDDs, PCDFs, MTLS, TOX, CL |
| Carbon Canister | Solid | Manual Composite | End of Test | Penta, PAHs, TR, PCDDs PCDFs |

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date: April 2, 1991

### 4.2.5 Health and Safety Protocols

Based on screening of the site and knowledge of the contaminants present, a "contaminated zone" including all process equipment was designated. This was primarily based on concern over dust. All activities within this area were carried out in modified Level D protection consisting of clothing to protect against dust, dust masks, face shields, and gloves. A decontamination area where personnel cleaned equipment, boots, etc., before leaving the area was designated.

## 4.3 MATERIAL CHARACTERIZATION

### 4.3.1 Feed Soils

Analyses of the several core samples taken from the Low Penta and the High Penta soil piles were used to establish that the average penta concentrations were as needed for the demonstration. In addition, a composite sample was also made from the individual samples and reanalyzed. The results of these analyses are summarized in Tables 4-8 and 4-9. The averages of the individual samples (133 and 512)are consistent with the anticipated values and with the values obtained later during the test program (130 mg/kg and 680 mg/kg, respectively); however, the analysis of the composited sample of the Low Penta soil pile was high at 450 mg/kg. The results are summarized in Tables 4-8 and 4-9 for the Low Penta and High Penta soil piles, respectively; results obtained for the Feed Soil during the demonstration are found in the discussion of each parameter.

The results of particle-size analysis for the Low Penta soil sample (SPL-C-00-PS) are shown in Table 4-10. It was composed of 5.74% gravel, 71.2% sand, and 4.54% silt and clay with 81.48% of the original sample weight accounted for.

Table 4-11 summarizes the results of the chemical analyses of the particle-sized fractions derived from the Low Penta soil sample. While the size distributions of the samples analyzed do not quite match the distribution in Table 4-10, the highest concentrations of contamination do occur in the soil fractions with the smallest grain sizes (<200 mesh), and the soil fraction with the largest grain sizes, the coarse oversize (>10 mesh). The bar chart in Figure 4-2 illustrates the distribution of penta mass for the different size ranges of soil particles and the percent of soil represented by each particle size range. From this figure it is clear that the "gravel and coarse sand" contribute the largest mass of penta and only account for 1/4 of the soil weight at the MacGillis and Gibbs site. This is probably the result of penta- and PAH-contaminated woody debris and tarry material. These tarry materials probably were more efficiently broken up during the demonstration soil washing than in the sieving studies.

TABLE 4-8. LOW PENTA SOIL ANALYSES - PENTA AND PAHs

| SAIC # | Penta | Fluorene | Q | Phenan-threne | Q | Anth-racene | Q | Fluor-anthene | Q | Pyrene | Q | Benzo-(a)-An-thracene | Q | Chrysene | Q | Benzo(b)-Fluor-anthene | Q | TOTAL PAHs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPL-01-00 | 150000 | 7100 | J | 20000 | | 86000 | | 12000 | | 29000 | | 3000 | J | 8000 | J | 2600 | * | 167700 |
| SPL-02-00 | 110000 | 13000 | | 37000 | | 100000 | | 21000 | | 30000 | | 5200 | J | 11000 | | 2600 | * | 219800 |
| SPL-03-00 | 190000 | 11000 | | 33000 | | 110000 | | 19000 | | 36000 | | 4600 | J | 11000 | | 2600 | * | 227200 |
| SPL-04-00 | 94000 | 13000 | | 41000 | | 110000 | | 21000 | | 36000 | | 4800 | J | 12000 | | 2600 | * | 240400 |
| SPL-05-00 | 120000 | 20000 | | 2600 | * | 250000 | | 13000 | | 23000 | | 3700 | J | 10000 | | 4400 | J | 326700 |
| SPL-06-00 | 130000 | 7300 | MJ | 21000 | M | 86000 | M | 14000 | M | 26000 | M | 4200 | MJ | 8900 | M J | 2600 | * | 170000 |
| SPL-07-00 | 120000 | 14000 | | 30000 | | 110000 | | 17000 | | 24000 | | 3300 | J | 8800 | | 3000 | Jh | 210100 |
| SPL-08-00 | 150000 | 6800 | J | 18000 | | 96000 | | 14000 | | 20000 | | 4100 | J | 9500 | J | 4100 | J | 172500 |
| SPL-C0-0 | | 19000 | | 64000 | | 38000 | J | 61000 | | 78000 | | 15000 | J | 22000 | J | 40000 | U | |
| AVERAGE | 133000 | 11525 | | 25325 | | 118500 | | 16375 | | 28000 | | 4113 | | 9900 | | 3063 | | 216800 |
| STD DEV | 27893 | 4218 | | 11618 | | 50584 | | 3389 | | 5500 | | 704 | | 1266 | | 702 | | 216800 |
| | | | | | | | | | | | | | | | | | | 49194.20 |

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TABLE 4-9. PENTA AND PAH CONCENTRATIONS
HIGH PENTA SOIL

| SAIC # | Penta | Acenaph-thene | Q | Fluorene | Q | Phenan-threne | Q | Anth-racene | Q | Fluor-anthene | Q | Pyrene | Q | Benzo-(a)an-thracene | Q | Chrysene | Q | Benzo(b)-Fluor-anthene | Q | Benzo(k) Fluor-anthene | Q | TOTAL PAHs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPH-01-00 | 130000 | 11000 | | 11000 | | 47000 | | 22000 | | 43000 | | 44000 | | 8000 | J | 16000 | | 3000 | * | 2700 | * | 207700 |
| SPH-02-00 | 380000 | 21000 | | 24000 | | 84000 | | 39000 | | 75000 | | 68000 | | 16000 | | 28000 | | 11000 | | 9500 | J | 375500 |
| SPH-03-00 | 660000 | 22000 | | 26000 | | 86000 | | 41000 | | 68000 | | 92000 | | 17000 | | 26000 | | 13000 | | 12000 | | 403000 |
| SPH-04-00 | 650000 | 14000 | | 11000 | | 38000 | | 19000 | | 62000 | | 49000 | | 15000 | | 21000 | | 16000 | | 2700 | * | 247700 |
| SPH-05-00 | 170000 | 24000 | | 27000 | | 92000 | | 45000 | | 76000 | | 97000 | | 19000 | | 31000 | | 12000 | | 14000 | | 437000 |
| SPH-06-00 | 570000 | 23000 | | 28000 | | 97000 | | 42000 | | 76000 | | 79000 | | 19000 | | 29000 | | 11000 | | 11000 | | 415000 |
| SPH-07-00 | 560000 | 25000 | | 28000 | | 110000 | | 46000 | | 77000 | | 77000 | | 20000 | | 29000 | | 11000 | | 11000 | | 434000 |
| SPH-08-00 | 830000 | 21000 | | 20000 | | 74000 | | 41000 | | 76000 | | 81000 | | 19000 | | 32000 | | 13000 | | 10000 | | 387000 |
| SPH-09-00 | 500000 | 16000 | | 15000 | | 53000 | | 31000 | | 65000 | | 86000 | | 17000 | | 28000 | | 11000 | | 12000 | | 334000 |
| SPH-10-00 | 660000 | 16000 | | 17000 | | 80000 | | 35000 | | 61000 | | 2600 | * | 15000 | | 23000 | | 8500 | J | 8500 | J | 266600 |
| SPH-11-00 | 590000 | 21000 | | 22000 | | 80000 | | 34000 | | 70000 | | 100000 | | 19000 | | 30000 | | 16000 | | 14000 | | 406000 |
| SPH-12-00 | 440000 | 21000 | | 20000 | | 74000 | | 31000 | | 85000 | | 59000 | | 20000 | | 30000 | | 13000 | | 11000 | | 364000 |
| Composite | 600000 | 17000 | | 18000 | | 78000 | | 38000 | | 61000 | | 78000 | | 15000 | J | 22000 | | 40000 | UJ | 40000 | UJ | |
| Average | 511667 | 19583 | | 20750 | | 76250 | | 35500 | | 69500 | | 69550 | | 17000 | | 26917 | | 11542 | | 9867 | | 356458 |
| Std. Dev. | 196080 | 4132 | | 5932 | | 20146 | | 8231 | | 10436 | | 26461 | | 3215 | | 4499 | | 3288 | | 3557 | | 73278 |

file: swhavg

TABLE 4-10.

PARTICLE-SIZE ANALYSIS OF LOW
CONCENTRATION SOIL SAMPLE SPL-C-00-PS
(1075 gm dry weight)

| Soil Fraction | Size Range | Dry Weight of Fraction (grams) | % of Soil Retained on Sieve |
|---|---|---|---|
| Gravel | 76.2mm to #4 sieve | 61.82 | 5.74 % |
| Coarse Sand | #4 to #10 sieve | 158.59 | 14.75 % |
| Medium Sand | #10 to #40 sieve | 461.76 | 42.94 % |
| Fine Sand | #40 to #200 sieve | 145.24 | 13.51 % |
| Fines (Silt/Clay) | below #200 sieve | 48.45 | 4.54 % |
| | Recovery | 875.86 | 81.5 % |

## TABLE 4-11. CHEMICAL ANALYSIS OF PARTICLE-SIZE FRACTIONS LOW PENTA CONCENTRATION SOIL SAMPLE

| Soil Fractions: | Feed Soil | Gravel and Coarse Sand | Medium Sand | Fine Sand | Fines (Silts/Clays) | |
|---|---|---|---|---|---|---|
| Description: | Composite | Mat'l retained on #3/8,#4,#10 seives | Mat'l retained on #20,#40 sieves | Mat'l retained on #60,#140,#200 sieve | Solid mat'l passing #200 sieve | Aqueous Sol'n passing #200 sieve |
| % of Sample *: | | 25.16 | 52.75 | 16.58 | 5.53 | NA |
| Organic Analyses: Units: | ug/kg | ug/kg | ug/kg | ug/kg | ug/kg | ug/kg |
| Pentachlorophenol | 133000 | 240000 | 42000 | 45000 | 240000 | NA |
| Fluorene | 19000 | ND | 3400 J | 1100 J | 14000 | NA |
| Phenanthrene | 64000 | 15000 | 7100 | 3100 | 31000 | NA |
| Anthracene | 38000 | 140000 | 45000 | 13000 | 230000 | NA |
| Fluoranthene | 61000 | 16000 | 4800 | 2200 | 21000 | NA |
| Pyrene | 78000 | 29000 | 6400 | 2800 | 40000 | NA |
| Benzo(a)anthracene | 15000 | ND | 1200 J | ND | ND | NA |
| Chrysene | 22000 | 12000 | 2800 J | 1300 J | 16000 | NA |
| Benzo(b)fluoranthene | 40000 | ND | 1000 J | ND | ND | NA |
| Inorganic Analyses: Units: | | mg/kg | mg/kg | mg/kg | mg/kg | mg/L |
| Arsenic | 13.1 | 13.3 | 2.9 | 2.4 | 17.5 | 3.6 |
| Chromium | 15.5 | 14 | 5.5 | 5.4 | 46 | 3.2 |
| Copper | 13.0 | 13.2 | 4.2 | 3.7 | 22.7 | 2.9 |

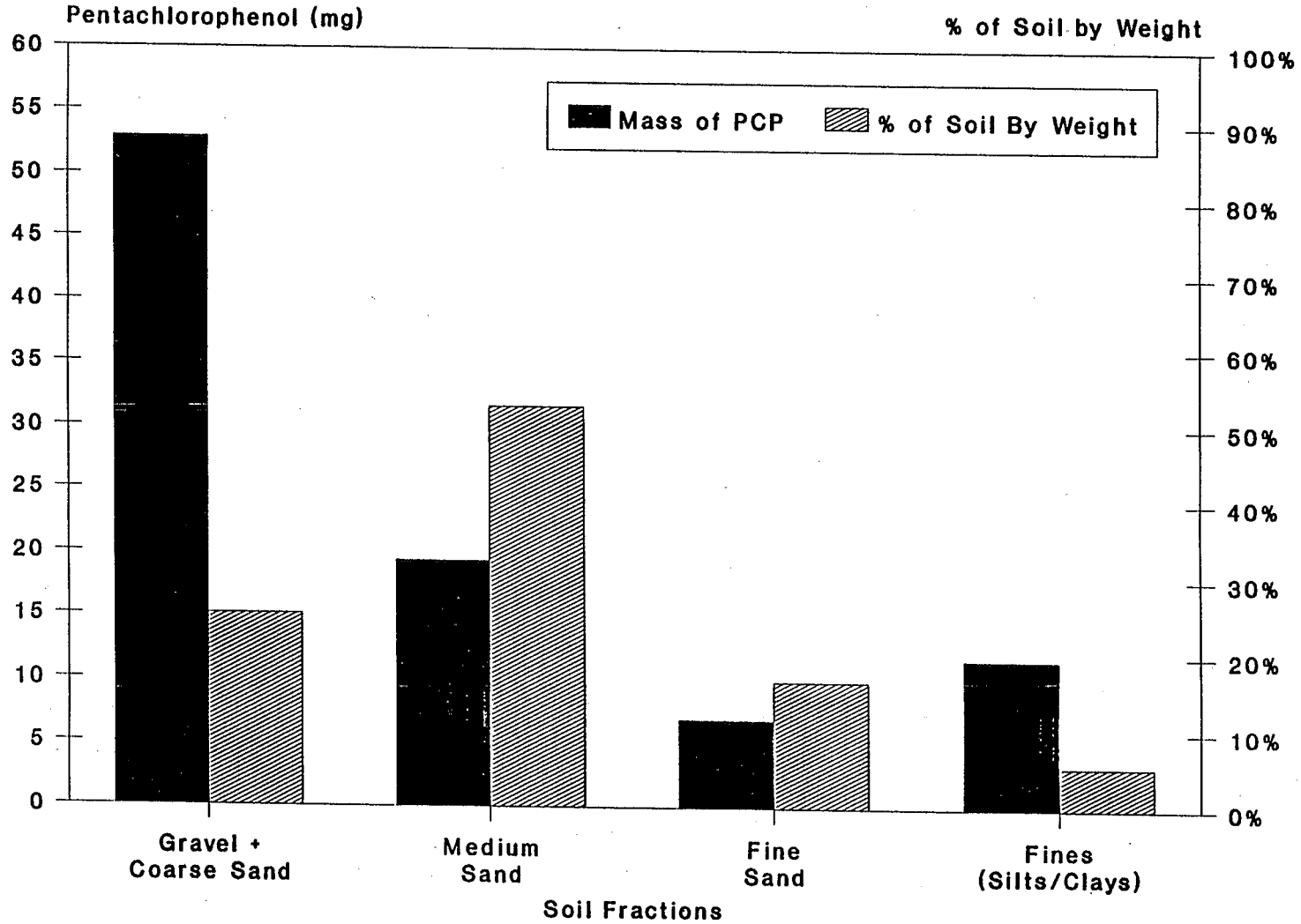
J – Indicates an estimated value. Used when a compound meets identification criteria and the result is less than the sample quantitation limit but greater than zero.
NA – Not analyzed. Original extracts lost; insufficient volume for re-extraction.
ND – Analyzed, not detected.
* – The percent is based on the amount of sample recovered from the sieves.

file: TAB4-11.WK1
date: April 2, 1991

# Fig 4-2. Particle-Size Fraction Analysis

## Low Penta Concentration Soil Sample

(1075 gm sample)




file name: LOWPCP.CHT

The original sample of High Penta soil (SPH-C-00-PS) was split into two samples of approximately equal weights (~500 gm each) and sieved wet using sodium hexametaphosphate or ASTM Type II water as the sieving solution. The results of both particle-size sieving analyses for the High Penta soil sample are shown in Tables 4-12 and 4-13 and indicate there was little difference in particle size distribution. The sample sieved with sodium hexametaphosphate was composed of 2.53% gravel, 83.83% sand particles, and 6.53% silt and clay with 92.9% recovery of the sample weight. The sample sieved with ASTM Type II water was composed of 2.53% gravel, 83.03% sand particles, and 7.40% silt and clay with 92.95% recovery of the sample weight.

Tables 4-14 and 4-15 show the results of the chemical analysis of the original High Penta soil and the particle-size fractions from the sodium hexametaphosphate solution and ASTM Type II water, respectively. While the contaminant distributions from the two solutions differ somewhat, the highest contaminant concentrations still occur in the fractions with the smallest and largest grain sizes. Figures 4-3 and 4-4 show the distribution of penta mass for different particle size fractions and the % of soil represented by this particle size range. Although each soil fraction contributes approximately the same penta mass, the gravel and coarse sand and the fines (silts/clays) account for only approximately 20% of the soil weight.

### 4.3.2 Soil Washer Output Streams

Samples of the solid process streams generated during the demonstration of the BSWS in both the Low Penta and the High Penta Soil Washer tests also were subjected to particle-size distribution and chemical analysis. These process streams were as follows:

- Washed Soil (WS)
- Fine Particle Cake (FPC)
- Fine Oversize (FO)
- Coarse Oversize (CO).

Tables 4-16 and 4-17 summarize the particle-size and chemical analysis results for the solid process output streams for the Low Penta and the High Penta soil washer tests, respectively.

Using the Unified Soil Classification System, the Washed Soil would be classified as a medium-grained sand with 93% and 96% of the solid mass falling in the sand range in the Low and High Penta tests, respectively. The Fine Particle Cake would be classified as fines (silts and clays) with 75% and 62%, respectively, of the mass falling in the fines range.

The Fine Oversize would be classified as a medium-grained sand with 85% and 77% of the particles falling in the sand range. However, the majority of the mass (76% and 73%) was retained on the #20 (0.85mm) sieve, the largest used in the particle-size analysis of this process stream. In addition, this material was described as looking like "peat moss" and consisting of very small organic fibers. Based on the laboratory description and using the USCS, the fine oversize could be classified as a highly organic soil.

TABLE 4-12. PARTICLE-SIZE ANALYSIS OF HIGH PENTA SOIL SAMPLE SPH-C-00-PS (SODIUM HEXAMETAPHOSPHATE SIEVING SOLUTION)
(442.3 gm dry weight)

| Soil Fraction | Size Range | Dry Weight of Fraction (grams) | % of Soil Retained on Sieve |
|---|---|---|---|
| Gravel | 76.2mm to #4 sieve | 11.19 | 2.53 % |
| Coarse Sand | #4 to #10 sieve | 27.13 | 6.13 % |
| Medium Sand | #10 to #40 sieve | 135.87 | 30.72 % |
| Fine Sand | #40 to #200 sieve | 207.8 | 46.98 % |
| Fines (Silt/Clay) | below #200 sieve | 28.88 | 6.53 % |
| | Recovery | 410.87 | 92.9 % |

TABLE 4-13. PARTICLE-SIZE ANALYSIS OF HIGH PENTA SOIL SAMPLE SPH-C-00-PS (ASTM TYPE II WATER SIEVING SOLUTION)
(464.0 gm dry weight)

| Soil Fraction | Size Range | Dry Weight of Fraction (grams) | % of Soil Retained on Sieve |
|---|---|---|---|
| Gravel | 76.2mm to #4 sieve | 11.74 | 2.53 % |
| Coarse Sand | #4 to #10 sieve | 28.47 | 6.14 % |
| Medium Sand | #10 to #40 sieve | 155.34 | 33.48 % |
| Fine Sand | #40 to #200 sieve | 201.43 | 43.41 % |
| Fines (Silt/Clay) | below #200 sieve | 34.34 | 7.4 % |
| | Recovery | 431.32 | 92.95 % |

TABLE 4-14. CHEMICAL ANALYSIS OF PARTICLE-SIZE FRACTIONS FOR HIGH PENTA CONCENTRATION SOIL SAMPLE SODIUM HEXAMETAPHOSPHATE SIEVING SOLUTION

| Soil Fractions: | Feed Soil | Gravel and Coarse Sand | Medium Sand | Fine Sand | Fines (Silts/Clays) | |
|---|---|---|---|---|---|---|
| Description: | Composite | Mat'l retained on #3/8,#4,#10 sieves | Mat'l retained o #20,#40 sieves | Mat'l retained on #60,#140,#200 sieve | Solid mat'l passing #200 sieve | Aqueous sol'n passing #200 sieve |
| % of Sample*: | | 9.33 | 33.07 | 50.58 | 7.03 | NA |
| Organic Analyses: | | | | | | |
| Units: | ug/kg | ug/kg | ug/kg | ug/kg | ug/kg | ug/L |
| Pentachlorophenol | 600000 | 1200000 D | 380000 D | 190000 | 1900000 D | NA |
| Acenaphthene | 17000 | 27000 | 10000 | ND | 48000 | NA |
| Fluorene | 18000 | 25000 | 11000 | ND | 44000 | NA |
| Phenanthrene | 78000 | 97000 | 40000 | 22000 | 160000 | NA |
| Anthracene | 36000 | 66000 | 23000 | ND | 68000 | NA |
| Fluoranthene | 70000 | 89000 | 40000 | 19000 | 160000 | NA |
| Pyrene | 54000 | 99000 | 43000 | 18000 | 150000 | NA |
| Benzo(a)anthracene | 17000 | 24000 | 8300 J | ND | 40000 | NA |
| Chrysene | 28000 | 40000 | 29000 | ND | 62000 | NA |
| Benzo(b)fluoranthene | 10000 | 10000 | ND | ND | 24000 | NA |
| Benzo(k)fluoranthene | 7300 J | ND | ND | ND | 20000 | NA |
| Benzo(a)pyrene | 53000 J | ND | ND | ND | 14000 | NA |
| Inorganic Analyses: | | | | | | |
| Units: | | mg/kg | mg/kg | mg/kg | mg/kg | mg/L |
| Arsenic | 21.9 | 41.1 | 8.3 | 5.4 | 33.5 | 7.21 |
| Chromium | 32.1 | 64.5 | 11.7 | 8.5 | 41.6 | 6.73 |
| Copper | 28.5 | 55 | 9.6 | 7 | 33.2 | 6.57 |

D – Indicates the compound was analyzed at a secondary dilution.

J – Indicates an estimated value. Used when a compound meets identification criteria and the result is less than the sample quantitation limit but greater than zero.

NA – Not analyzed. Original extracts lost; insufficient volume for re-extraction.

ND – Analyzed, not detected.

* – The percent is based on the amount of sample recovered from the sieves.

TABLE 4-15. CHEMICAL ANALYSIS OF PARTICLE-SIZE FRACTIONS FOR HIGH PENTA CONCENTRATION SOIL SAMPLE
ASTM TYPE II WATER SIEVING SOLUTION

| Soil Fractions: | Feed Soil | Gravel and Coarse Sand | Medium Sand | Fine Sand | Fines (Silts/Clays) | |
|---|---|---|---|---|---|---|
| Description: | Composite | Mat'l retained on #3/8,#4,#10 sieves | Mat'l retained on #20,#40 sieves | Mat'l retained on #60,#140,#200 sieve | Solid mat'l passing #200 sieve | Aqueous sol'n passing #200 sieve |
| % of Sample*: | 100 | 9.32 | 36.02 | 46.70 | 7.96 | NA |
| Organic Analyses: | | | | | | |
| Units: | ug/kg | ug/kg | ug/kg | ug/kg | ug/kg | ug/L |
| Pentachlorophenol | 600000 | 1200000 D | 250000 D | 160000 D | 1100000 D | NA |
| Acenaphthene | 17000 | 27000 | 6600 | 4700 DJ | 22000 | NA |
| 2,3,5,6-Tetrachlorophenol | --- | ND | 15000 | ND | 51000 | NA |
| Fluorene | 18000 | 25000 | 4600 | 4400 DJ | 19000 | NA |
| Phenanthrene | 78000 | 97000 | 18000 | 17000 D | 130000 D | NA |
| Anthracene | 36000 | 66000 | 19000 | 8500 D | 32000 | NA |
| Fluoranthene | 70000 | 89000 | 29000 | 21000 D | 200000 D | NA |
| Pyrene | 54000 | 99000 | 26000 | 19000 D | 160000 D | NA |
| Benzo(a)anthracene | 17000 | 24000 | 6300 | 4200 DJ | 18000 | NA |
| Chrysene | 28000 | 40000 | 14000 | 7400 DJ | 30000 | NA |
| Benzo(b)fluoranthene | 10000 | 10000 | 4900 | ND | 13000 | NA |
| Benzo(k)fluoranthene | 73000 J | ND | 4500 | ND | 10000 | NA |
| Benzo(a)pyrene | 53000 J | ND | 2400 J | ND | 8400 | NA |
| Inorganic Analyses: | | | | | | |
| Units: | | mg/kg | mg/kg | mg/kg | mg/kg | ug/L |
| Arsenic | 21.9 | 41.1 | 5.9 | 7.2 | 67 | 376 |
| Chromium | 32.1 | 64.5 | 20.8 | 7.6 | 97.4 | 283 |
| Copper | 28.5 | 55 | 10.4 | 6.7 | 78.6 | 342 |

D - Indicates the compound was analyzed at a secondary dilution.

J - Indicates an estimated value. Used when a compound meets identification criteria but the result is less than the sample quantitation limit but greater than zero.

NA - Not analyzed. Original extracts lost; insufficient volume for re-extraction.

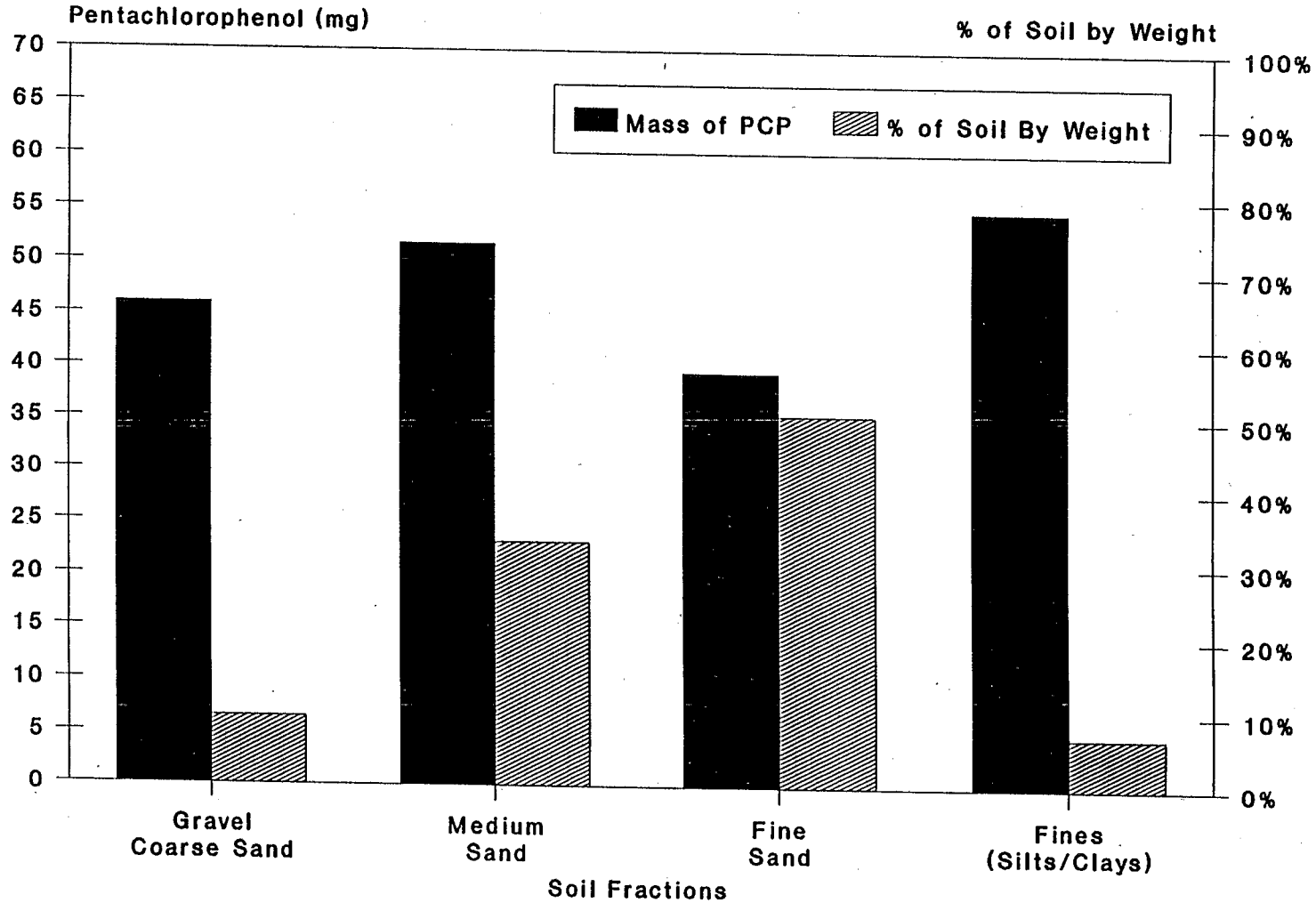
ND - Analyzed, not detected.

* - The percent is base on the amount of sample recovered from the sieves.

# Fig 4-3. Particle-Size Fraction Analysis

## High Penta Concentration Soil Sample

(442 gm sample)



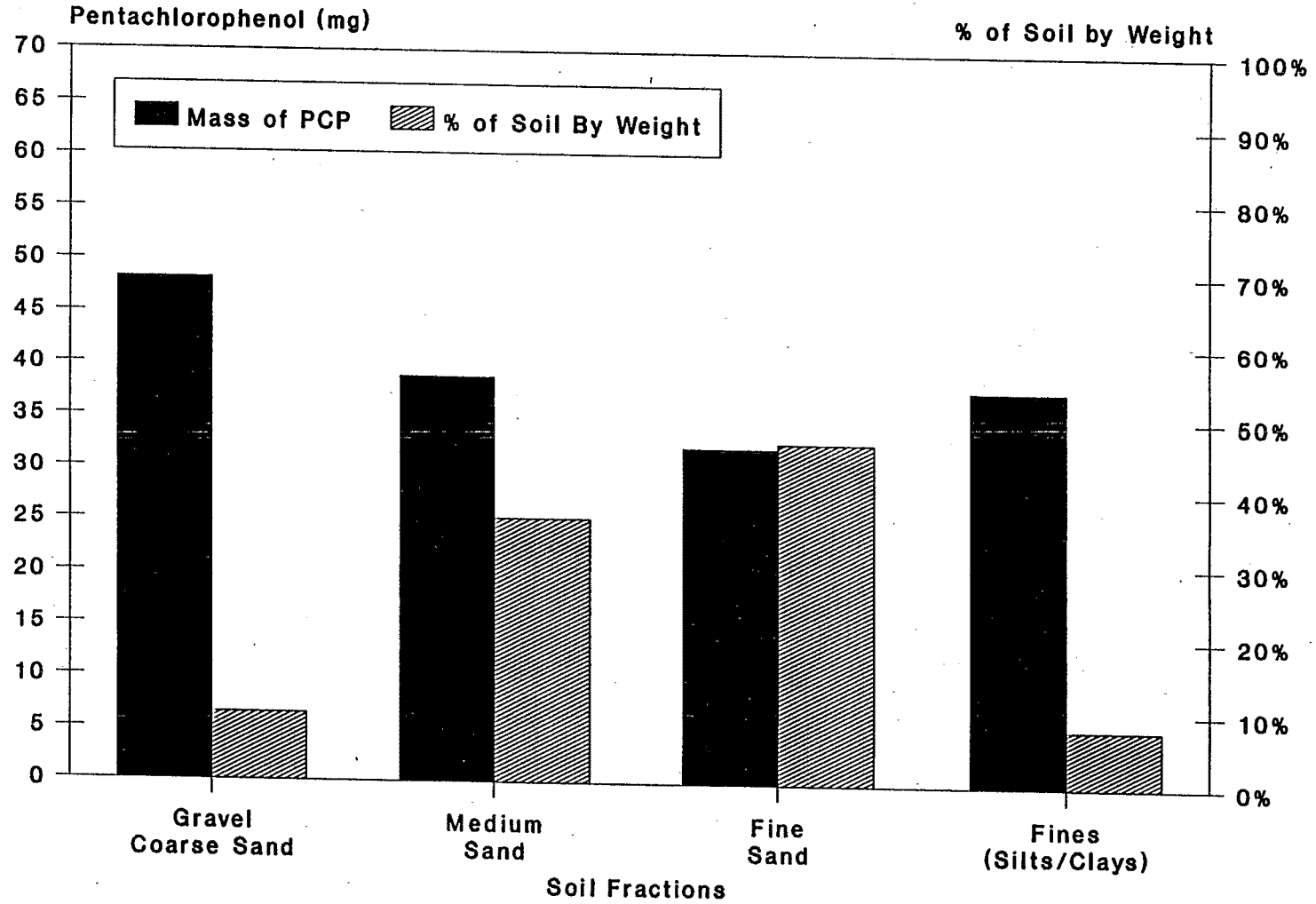

Sodium Hexametaphosphate Sieving Sol'n

filename: PCPA.CHT

# Fig 4-4. Particle-Size Fraction Analysis

## High Penta Concentration Soil Sample

(464 gm sample)




ASTM Type II Water Sieving Sol'n

file name: PCPB.CHT

TABLE 4–16. PARTICLE SIZE ANALYSIS AND CHEMICAL ANALYSIS OF SOLID PHASE STREAMS
LOW PENTA SOIL TEST

| Sample ID: | SWL–CO–O | SWL–WS–02–3 | SWL–FPC–02–1 | SWL–FO–01– | SWL–CO–01–3 |
|---|---|---|---|---|---|
| Process Stream: | Feed Soil | Washed Soil | Fine Particle Cake | Fine Oversize | Coarse Oversize |
| Particle–Size Results | | | | | |
| Sieve #/Fraction Size | | Soil on Sieve | Soil on Sieve | Soil on Sieve | Soil on Sieve |
| #3/8 / 9.50mm | | + | + | + | 9% |
| #4 / 4.75mm | 6% | + | + | + | 21% |
| #10 / 2.00mm | 15% | + | + | + | 30% |
| #20 / .850mm | | 3% | + | 76% | 38% |
| #40 / .425mm | 43% | 76% | 8% | 3% | 1% |
| #60 / .250mm | | 7% | 5% | 2% | 1% |
| #140 / .106mm | | 6% | 3% | 3% | 1% |
| #200 / .075mm | 14% | 1% | 3% | 1% | 1% |
| PAN | 5% | 2% | 75% | 6% | 3% |
| Total % Recovery | 82% | 95% | 94% | 91% | 105% |
| Analytical Results* | | | | | |
| Pentachlorophenol | 133000 ** | 19000 | 210000 | 130000 | 190000 E |
| Fluorene | 19000 J | ND | 43000 | 33000 | 15000 |
| Phenanthrene | 64000 | 870 J | 120000 | 74000 | 38000 |
| Anthracene | 38000 J | 5200 | 490000 D | 260000 | 68000 E |
| Fluoranthene | 61000 | 1500 J | 42000 | 18000 | 14000 |
| Pyrene | 78000 | 2900 | 83000 | 15000 | 21000 |
| Benzo(a)anthracene | 15000 J | 330 J | 12000 | 3700 J | 3300 |
| Chrysene | 22000 J | 1200 J | 34000 | 9800 J | 8800 |
| Benzo(b)fluoranthene | 40000 | ND | 6500 J | 2400 J | 1700 J |
| Copper (mg/kg) | 13.1 | 5 | 44.9 | 8.8 | 15 |
| Chromium (mg/kg) | 15.5 | 6.4 | 47.6 | 9.7 | 22.4 |
| Arsenic (mg/kg) | 13 | 3.9 | 41.9 | 7.5 | 5.6 |

+ – Sieve not used in particle-size analysis of this sample.
* – All analytical results are reported in ug/kg unless otherwise noted.
** – Averaged value used, composite value was 450000 ug/kg
E – Indicates the concentration of a compound exceeds the calibration range.
D – Indicates the compound was analyzed at a secondary dilution.
J – Indicates an estimated value. Used when a compound meets identification criteria and the result is less than the sample quantitation limit but greater than zero. ND – Analyzed, not detected.

TABLE 4-17. PARTICLE SIZE ANALYSIS AND CHEMICAL ANALYSIS OF SOLID PROCESS STREAMS
HIGH PENTA SOIL TEST

| Sample ID: | SWH-C0- | SWH-WS-05-2 | SWH-FPC-06-3 | SWH-FO-01- | SWH-CO-02-1 |
|---|---|---|---|---|---|
| Process Stream: | Feed Soil | Washed Soil | Fine Particle Cake | Fine Oversize | Coarse Oversize |
| Particle-Size Results<br>Sieve #/Fraction Size | | Soil on sieve | Soil on sieve | Soil on sieve | Soil on sieve |
| #3/8 / 9.50mm | + | + | + | + | 5% |
| #4 / 4.75mm | 3% | + | + | + | 16% |
| #10 / 2.00mm | 6% | + | + | + | 28% |
| #20 / .850mm | + | 4% | + | 73% | 46% |
| #40 / .425mm | 31% | 63% | 4% | 1% | 2% |
| #60 / .250mm | + | 19% | 12% | 1% | 2% |
| #140 / .106mm | + | 9% | 11% | 1% | 3% |
| #200 / .075mm | 47% | 1% | 11% | 1% | 1% |
| PAN | 6% | 2% | 62% | 24% | 3% |
| Total % Recovery | 93% | 98% | 100% | 101% | 106% |
| Analytical Results* | | | | | |
| Pentachlorophenol | 600000 | 110000 | 1500000 D | 430000 D | 1000000 D |
| Fluorene | 18000 | 4300 | 56000 | 14000 | 22000 |
| Phenanthrene | 78000 | 16000 | 240000 D | 47000 D | 81000 D |
| Anthracene | 36000 | 6700 | 130000 D | 42000 BD | 33000 DJ |
| Fluoranthene | 70000 | 17000 | 180000 D | 39000 | 74000 D |
| Pyrene | 54000 | 11000 | 200000 D | 35000 D | 60000 D |
| Benzo(a)anthracene | 17000 | 3100 J | 59000 DJ | 9100 | 14000 |
| Chrysene | 28000 | 5600 | 65000 DJ | 17000 | 26000 |
| Benzo(b)fluoranthene | 10000 | 1900 J | 31000 | 6000 | 7800 J |
| Copper (mg/kg) | 28.5 | 20.6 | 120 | 17.3 | 36.7 |
| Chromium (mg/kg) | 32.1 | 33 | 113 | 24.8 | 80.8 |
| Arsenic (mg/kg) | 21.9 | 11.8 | 80.8 | 16.8 | 36.6 |

+ - Sieve not used in particle-size analysis of this sample.
* - All analytical results are reported in ug/kg unless otherwise noted.
B - Indicates the compound was found in the associated method blank.
D - Indicated the compound was analyzed at a secondary dilution.
E - Indicates the concentration of a compound exceeds the calibration range.
J - Indicates and estimated value. Used when a compound meets identification criteria and the result is less than the sample quantitation limit but greater than zero.

The Coarse Oversize would be classified as a coarse-grained sand based on the predominant particle-size falling in the sand range (72% and 82% respectively). The Coarse Oversize sample from the Low Penta Soil Washer test also contained 30% gravel (9% coarse gravel and 21% fine gravel). The Coarse Oversize sample from the High Penta Soil Washer test contained 21% gravel (5% coarse gravel and 16% fine gravel).

The highest concentrations of contamination occur in the Coarse Oversize (gravel and coarse sand) and Fine Particle Cake (fines - silts and clays). This agrees with the results of the particle-size analysis of the Feed Soil, where the contaminants were concentrated in the gravel, coarse sand, and fines (silts and clays) fractions.

Thus, the chemical analyses indicate that the highest concentrations of contamination occurs in the soil fractions with the smallest grain sizes (<200 mesh) as well as in the soil fraction with the largest grain sizes (>10 mesh).

## 4.4 PILOT SYSTEM PERFORMANCE RESULTS

### 4.4.1. Introduction

The results of the evaluation of the three technologies are complex and multi-faceted. To assist the reader, the processes are presented in what seemed to be a logical sequence, first addressing the Soil Washer, then the BATS, and finally the SBR. Generally, the results for each technology is: (a) material balance, (b) penta and PAH data, (c) TOC and TRPH results, (d) metals, beginning with chromium, copper and arsenic and finishing with other metals, and (e) EP toxicity data. The discussion of the Soil Washer performance also includes, after the analytical results, a discussion of the flow rate stability and its impact on the various output fractions and the contaminants in each. Within each subsection the results for the Low Penta are always discussed before the High Penta results.

Finally, after the discussions of the results of the three technologies are essentially complete, the results for dioxin determinations in the three technologies are reported and discussed in a separate section.

### 4.4.2 Soil Washer Performance

Considerable variation in feed and output stream rates was observed. Consequently, analytical data for contaminant concentrations in the input and output streams have been weighted on the basis of input or output stream flows or masses. These weighted values were the basis for most of the calculations in this report. This helps smooth the data, and it also makes material or mass balances somewhat more indicative of overall system performance. Recognizing that the Soil Washer is a complex mechanical operation and exhibited some of the problems inherent when operating at the pilot-plant scale, this approach was considered the most practical. Nevertheless, the following table (Table 4-18) provides a comparison of average concentrations and weighted concentrations for the Low Penta and the High Penta Soil Washer tests.

TABLE 4-18. COMPARISON OF AVERAGE AND WEIGHTED AVERAGE CONCENTRATIONS (mg/kg or mg/L)

| | Low Penta SW test | | High Penta SW test | |
|---|---|---|---|---|
| | avg. | wtd avg | avg | wtd avg |
| Feed Soil | 112.8±20 | 130 | 657.8±228 | 680 |
| Washed Soil | 12.5±4.5 | 14 | 85.3±31 | 87 |
| Fine Oversize | 85.7±34 | 96 | 854.4±360 | 900 |
| Coarse Oversize | 155.1±51 | 170 | 1346 ±650 | 1400 |
| Fine Particle Cake | 241.1±74 | 270 | 1274 ±390 | 1300 |
| Combined Dewater. Eff. | 12.6±3.4 | 14 | 74.8±36 | 80 |

One of the problems recognized even before the project was initiated was that the approved analytical methods for organic contaminant concentrations in Feed Soil and the several output solid streams were measured by sonication of the soil in an organic solvent (e.g., methylene chloride) followed by GC/MS of the extracts. This sonication process probably achieves equilibration of the contaminants between the solvent and the accessible soil particle surfaces. However, BioTrol's Soil Washer uses high energy abrasion of soil particles against each other in a water matrix, separating soil particles which are stuck together and abrading organic matter from the particle surfaces. This may open up the matrix of the soil more than the laboratory sonication process and consequently allow more complete extraction of the contaminants during subsequent analysis of the output streams.

A second aspect of the soil washing process is the extraction step that unavoidably occurs during the soil washing; the mass of contaminants found in the output streams is the sum of the contaminants extracted by a water extraction step (the soil washing process) and a solvent extraction step. This extra water extraction step that the Feed Soil is not subjected to, and the hydration of the soil matrix before solvent extraction, may also have contributed to the greater mass of pentachlorophenol found in the output streams compared to the input soil.

Finally, to provide a common basis for discussion of results, all data have been reduced to the processing of 1 kg of Feed Soil in both the Low Penta and the High Penta tests. Contaminant removal efficiency for the Soil Washer was assessed by comparing the concentration (or mass) of a contaminant in the "as is" Feed Soil and Washed Soil, using the equation:

$$\% \text{ Removal Efficiency} = \left(1 - \frac{\text{Conc. in Washed Soil}}{\text{Conc. in Feed Soil}}\right) \times 100$$

as defined by BioTrol in its original claims. Because of fluctuations in material flows in some portions of the study, which suggested that concentrations were not a true indicator of the character of the fractions or the distribution of the contaminants, this was converted to a mass basis, using the equation:

$$\% \text{ Removal Efficiency} = \left(1 - \frac{\text{Mass in Washed Soil}}{\text{Mass in Feed Soil}}\right) \times 100$$

where mass refers to the weighted mass over the course of a test or, as standardized in this report, per unit (1 kg) of Feed Soil.

While these equations do not take into consideration the difference in mass between the Feed Soil and the Washed Soil product, they do, nevertheless, give a good indication of the amount of contaminant that would be present in the major output stream, the material expected to be returned to the site.

It is also interesting to note that even though large discrepancies in the mass balance (i.e., closure) were observed, the effects on the % Removal Efficiency are small. For example, if the % Removal Efficiency for the High Penta Soil Washing test is restated, using the ratio of the mass of penta in the Washed Soil to the mass of penta recovered in all output streams, the change is only from 83% to 89%. And, if % Removal Efficiency is calculated on the assumption that the Feed Soil penta concentration is biased 50% low because of poor accessibility and a Feed Soil value 50% higher is used (1.5 x 680 ppm = 1020 ppm), the calculated value is then 91.4%.

| Basis | % Removal Efficiency |
|---|---|
| Concentration, WS/FS | 87 |
| Mass, WS/FS | 83 |
| Mass, WS/Total Output | 89 |
| Conc., Feed Soil @ 1020 ppm | 91 |

#### 4.4.2.1 As-Is Material Balance

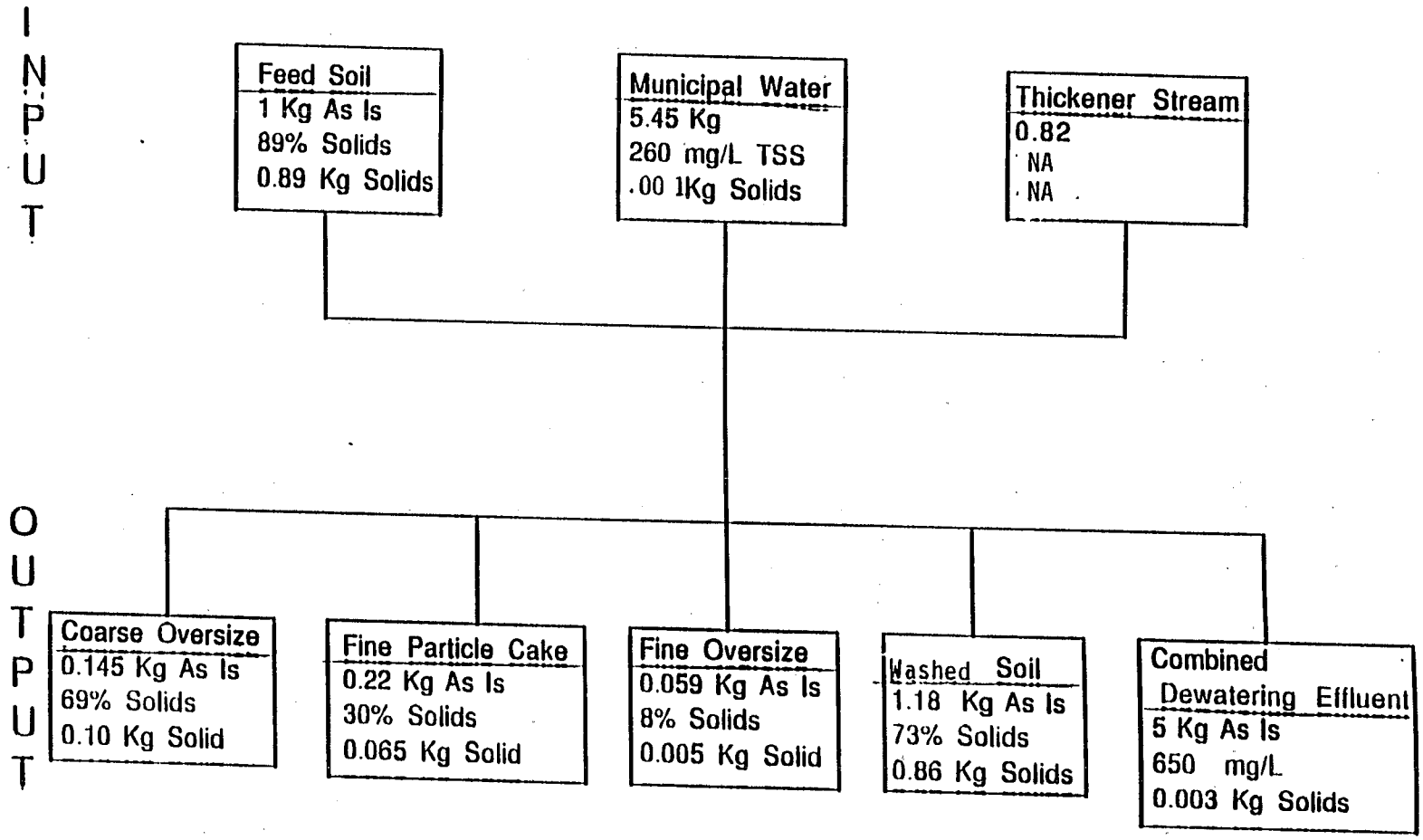
During the Low Penta SW test, carried out for 50 hrs, a total of 11,000 kg of "as-is" Feed Soil was treated at rates ranging from 110 kg/hr to 300 kg/hr. On that basis, the weighted feed rate was, then, 220 kg/hr. To achieve the desired consistency for processing, a total of 70,100 kg of water was added, mostly as municipal water. Thus, for each kg of Feed Soil, a weighted average of 6.27 kg of water was also processed. Since the as-is Feed Soil contained 11% water, 1 kg contains 0.89 kg of dry soil. Table 4-19 summarizes the mass flows in the Low Penta Soil Washer test.

Processing yielded - on an as-is basis - 1.18 kg of Washed Soil, 0.22 kg of Fine Particle Cake, 0.145 kg of Coarse Oversize, and 0.059 kg of Fine Oversize plus 5.0 kg of Combined Dewatering Effluent. On this basis, the material balance indicates that 7.27 kg of input (Feed Soil plus water) produced 6.6 kg of output; the difference is approximately -9% which, considering the scale of the operations, is not considered excessive. Of key significance are the large mass of Washed Soil (1.18 kg) that would be returned to the site if it meets regulatory agency requirements and the small mass of Fine Particle Cake (0.22 kg) that would require additional treatment or disposal. Figure 4-5 and 4-6 present the input and output streams in a more graphical manner.

TABLE 4-19. FATE OF MATERIALS-LOW PENTA SOIL WASHER TEST
(Average Input Rate: 220 kg/hr)

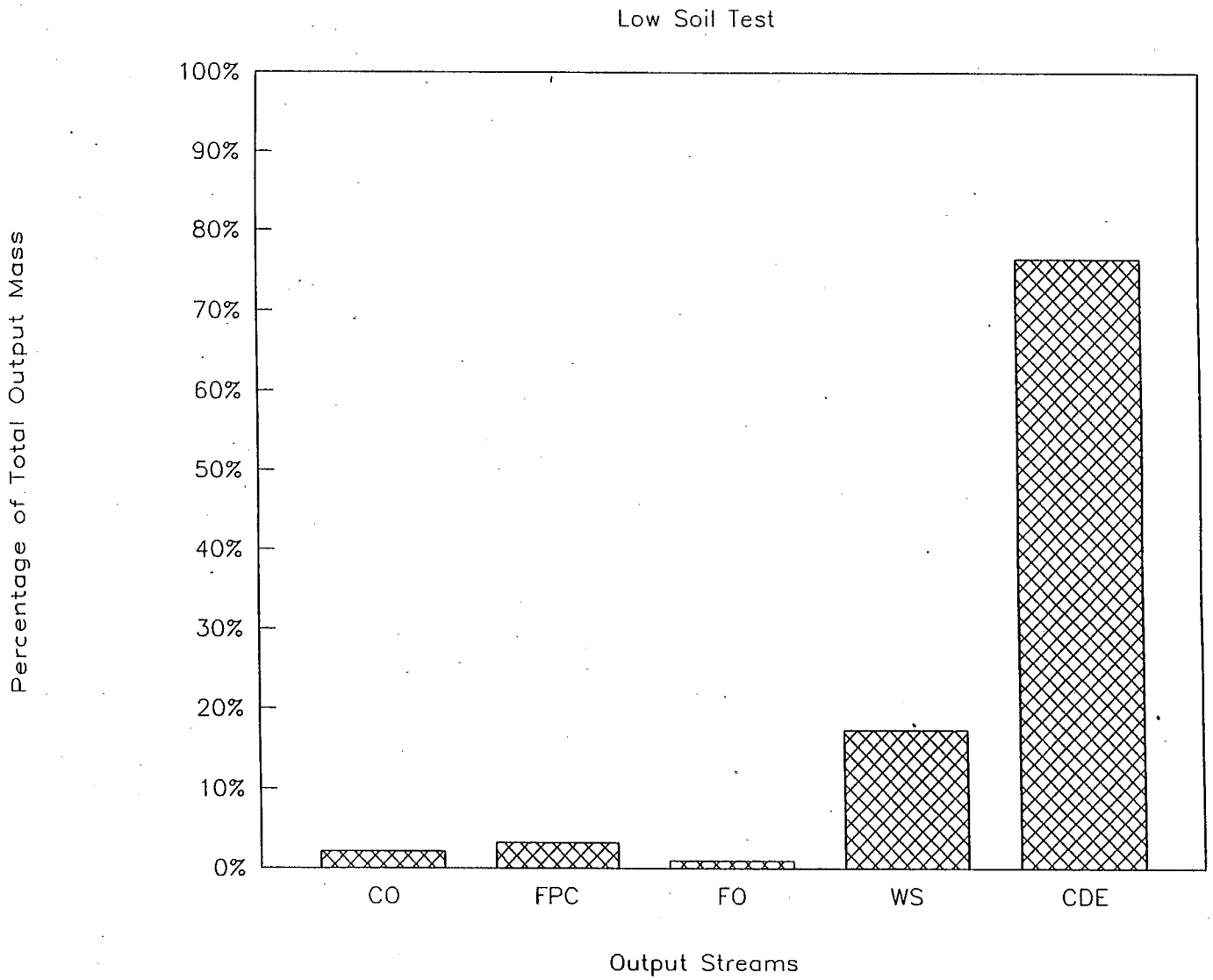
| Input Stream | Kg as-is | % of Input as-is | Solids Content | Solids kg (dry wt) | Solids % of Input |
|---|---|---|---|---|---|
| Feed Soil (FS) | 1 | 14 | 89 % | 0.89 | 99.9 |
| Municipal Water (MW) | 5.45 | 76 | 260 mg/L | 0.001 | 0.1 |
| Thickener Solution (T) | 0.82 | 10 | NA | NA | --- |
| TOTAL | 7.27 | 100 | --- | 0.891 | 100 |
| **Output Stream** | **Kg as-is** | **% of Output as-is** | **Solids Content** | **Solids kg (dry wt)** | **Solids % of Output** |
| Washed Soil (WS) | 1.18 | 17.4 | 73% | 0.861 | 83.3 |
| Coarse Oversize (CO) | 0.14 | 2.1 | 69% | 0.097 | 9.4 |
| Fine Particle Cake (FPC) | 0.22 | 3.2 | 30% | 0.066 | 6.4 |
| Fine Oversize (FO) | 0.06 | 0.9 | 8% | 0.005 | 0.5 |
| Combined Dewatering Eff. (CDE) | 5 | 76.4 | 650 mg/L | 0.003 | 0.3 |
| TOTAL | 6.6 | 100 | --- | 1.032 | |

FIG. 4-5. MASS DISTRIBUTION IN LOW SOIL TEST




| | Input | Output | % Diff. |
|---|---|---|---|
| TOTAL MASS | 7.27 Kg | 6.6 Kg | -9.2 |
| SOLIDS MASS | 0.891 Kg | 1.033 | +15.9 |

FIGURE 4-6. Distribution of Total Output Mass



In the High Penta SW test, the average processing rate over 112 operating hours was 160 kg/hr, with considerable variation as discussed later in the subsection concerning flow rate variability (Section 4.4.2.8).

Over the course of the test, each kilogram of as-is Feed Soil (with an average 84% solids, or 0.84 kg solids) was mixed with an additional 5.09 kg of water, composed of 4.12 kg of treated effluent from the BATS, 0.22 kg of municipal water, and 0.75 kg of the cationic polymer solution used to assist dewatering. The masses of the output streams shown in Table 4-20 and Figures 4-7 and 4-8. Based on the total output of 6.27 kg from an input of 6.1 kg, the difference, approximately 3%, is not significant.

Comparison of the water input and output streams indicates that 1.2 kg and 0.5 kg of water is retained by the solid output streams from the Soil Washer during the Low Penta test and the High Penta test, respectively. This water would have to be made up from some outside source if further recovery of water is not possible by improved dewatering of solid streams.

#### 4.4.2.2 Dry Solids Material Balance

Each 1.0 kg of as-is Feed Soil (Low Penta SW test) contains an average of 89% solids or 0.89 kg based on Total Solids analyses. Similarly, the solid output streams retain varying amounts of water. Based on Total Solids analyses, the output streams contain 1.033 kg of solids, including the suspended solids in the Combined Dewatering Effluent (CDE). Compared to the 0.891 kg of solids in the input (including the suspended solids in the municipal water) this represents an apparent 16% increase. While this is no longer insignificant, it may reflect small changes in large weight values, i.e., the precision of the various weighings, particularly the Feed Soil and the Washed Soil, or subsequent rounding of values during calculations. While the results (summarized in Table 4-19 and Figures 4-5 and 4-6) can be used to infer that 97% of the Feed Soil solids left the system as dry Washed Soil in the Low Penta SW test, the reader is cautioned against making such an interpretation because of the uncertainty created by the 16% increase in solids.

In the High Penta SW test, each 1.0 kg of as-is Feed Soil contains 0.84 kg of solids. The calculated total solids in the output streams amount to 1.086 kg, including the small amount of solids in the CDE (Table 4-20 and Figures 4-7 and 4-8). The change from the input is now 29%, which is large and difficult to explain. As a result of this increase, a value can not be calculated for recovery of the Washed Soil since the Washed Soil output (on both the as-is and dry weight basis) is greater than the input.

#### 4.4.2.3 Penta Distribution - Low Penta SW Test

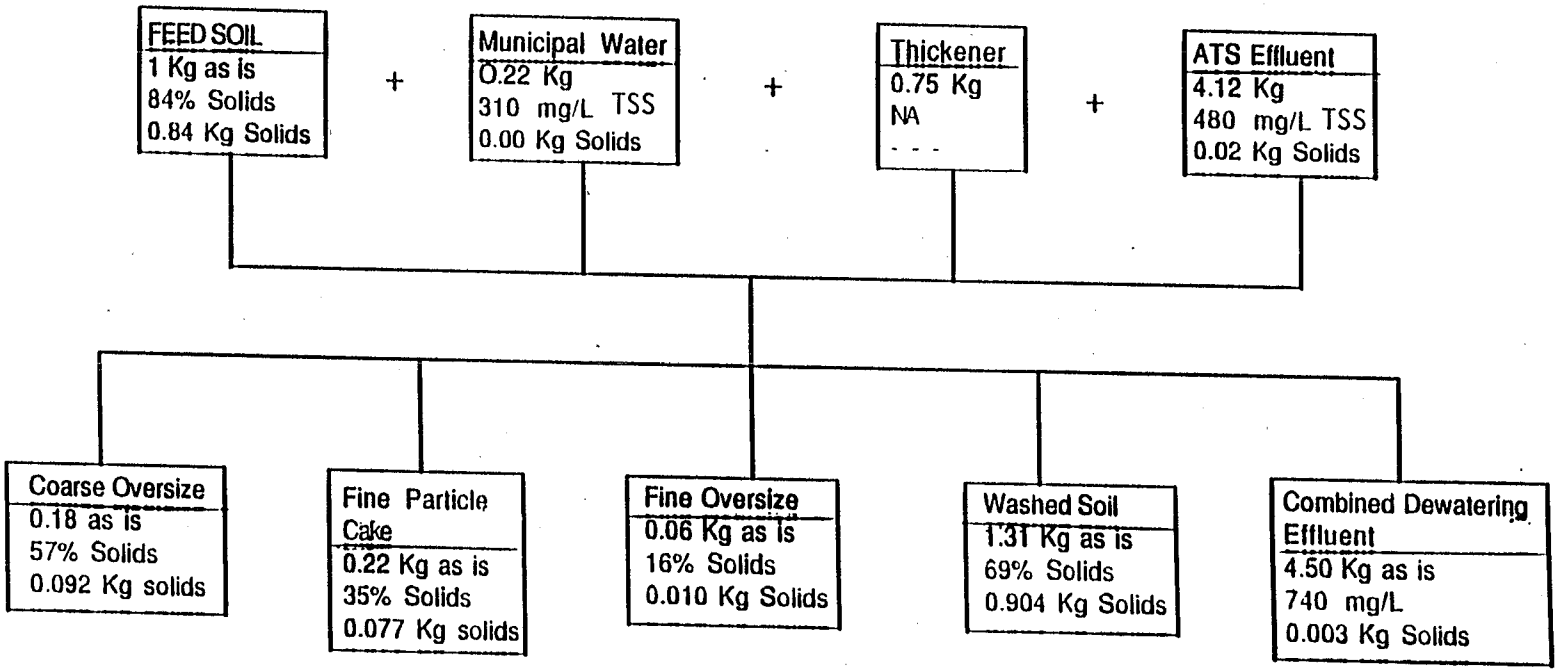
Samples of each input and output stream were analyzed for penta. The analytical results were converted to mass on the basis of the weights for each interval sampled and weighted concentrations then calculated from the total penta mass and the total input or output stream mass. These weighted results are presented in Table 4-21 and Figure 4-9. Using the change in weighted concentration from the Feed Soil to the Washed Soil, the average penta Removal

TABLE 4-20. FATE OF MATERIALS-HIGH PENTA SOIL WASHER TEST
Average Input Rate: 160 Kg/hr

| Input Stream | Kg as-is | % of Input as-is | Solids Content | Solids Kg (dry wt) | Solids % of Input |
|---|---|---|---|---|---|
| Feed Soil (FS) | 1 | 16 | 84% | 0.84 | 99.8 |
| Municipal Water (MW) | 0.22 | 4 | 310 mg/L | 0 | |
| Thickener Solution (T) | 0.75 | 12 | NA | -- | |
| ATS Effluent (ATS) | 4.12 | 68 | 480 mg/L | 0.002 | 0.2 |
| TOTAL | 6.09 | 100 | --- | 0.842 | |
| **Output Stream** | **Kg as-is** | **% of Output as-is** | **Solids Content** | **Solids Kg (dry wt)** | **Solids % of Output** |
| Washed Soil (WS) | 1.31 | 20 | 69% | 0.904 | 83.2 |
| Coarse Oversize (CO) | 0.18 | 3 | 51% | 0.092 | 8.5 |
| Fine Particle Cake (FPC) | 0.22 | 3 | 35% | 0.077 | 7.1 |
| Fine Oversize (FO) | 0.06 | 1 | 16% | 0.01 | 0.9 |
| Combined Dewatering Effl. | 4.5 | 73 | 740 mg/L | 0.003 | 0.3 |
| TOTAL | 6.27 | 100 | --- | 1.086 | |

file: 4-17.WK1

## FIGURE 4-7. MASS DISTRIBUTION IN HIGH SOIL TEST




| | INPUT | OUTPUT | % DIFF |
|---|---|---|---|
| TOTAL MASS | 6.09 | 6.27 | 3.0 |
| SOLID MASS | 0.842 | 1.086 | 29.0 |

FIGURE 4-8. Distribution of Total Output Mass

High Penta Soil Test

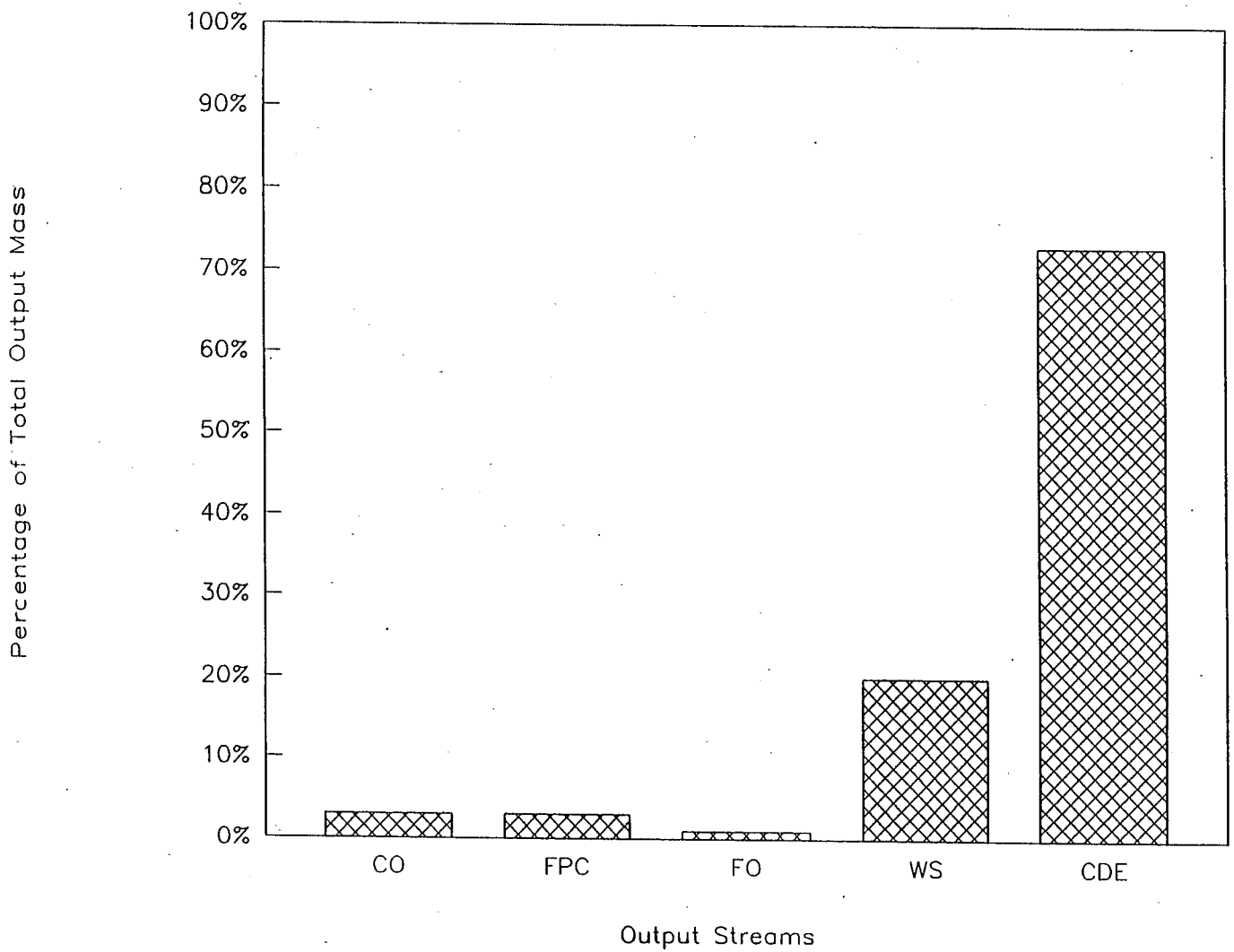


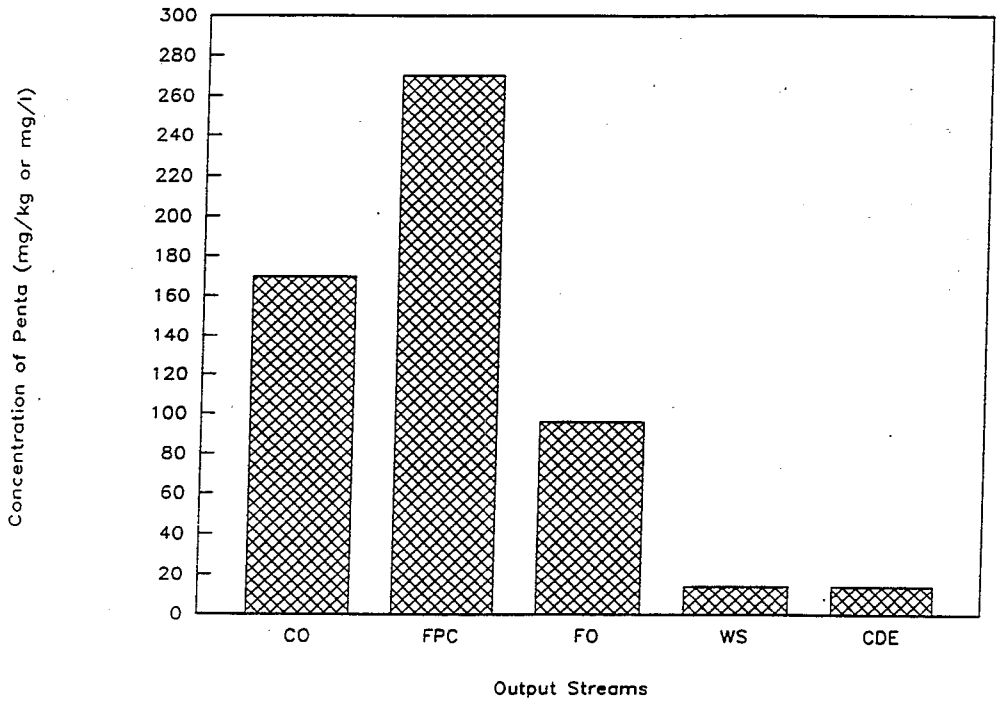
TABLE 4-21. AVERAGE PENTA DISTRIBUTION-LOW PENTA SOIL WASHER TEST

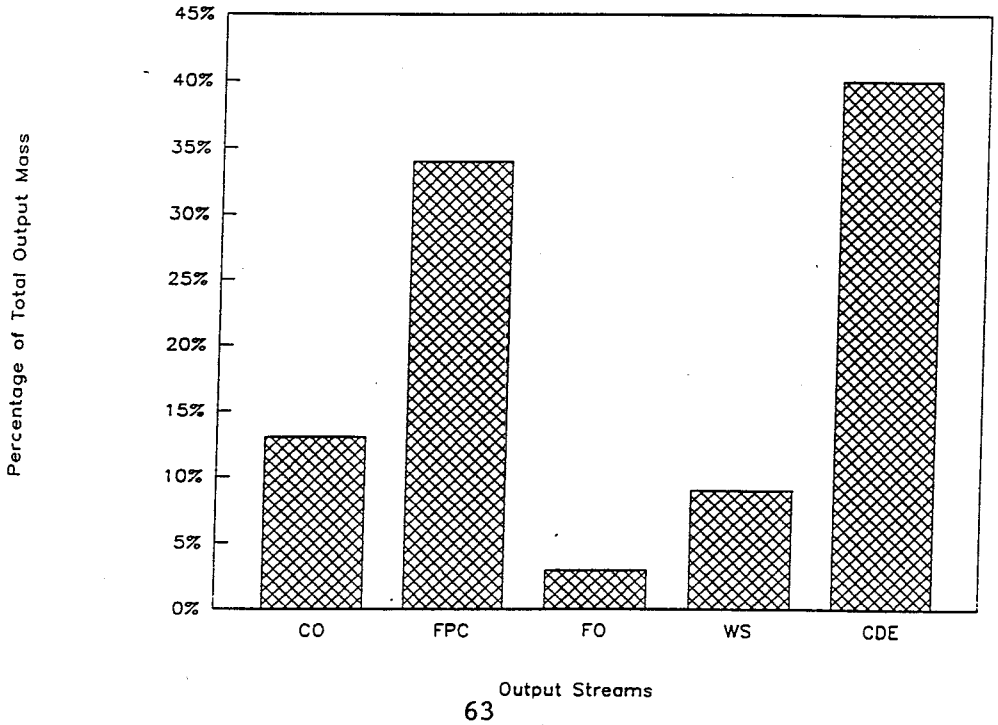
| INPUT | Stream As Is wt. (Kg) | Conc. (ppm) | Penta Mass mg | Dist. (%) | Calc. Conc. on Solids (ppm) |
|---|---|---|---|---|---|
| Feed Soil | 1.00 | 130 | 130 | 100 | 144 |
| Municipal Water | 5.45 | 0 | 0 | 0 | |
| Thickener Sol'n | 0.82 | 0 | 0 | 0 | |
| TOTAL | 7.27 | | 130 | | |
| **OUTPUT** | **Stream As Is wt. (Kg)** | **Conc. (ppm)** | **Penta Mass mg** | **Dist. (%)** | **Calc. Conc. on Solids (ppm)** |
| WS | 1.18 | 14 | 16.5 | 9 | 14 |
| CO | 0.14 | 170 | 23.8 | 13 | 239 |
| FPC | 0.22 | 270 | 59.4 | 34 | 953 |
| FO | 0.06 | 96 | 5.8 | 3 | 1042 |
| CDE | 5.00 | 14 | 70 | 40 | |
| TOTAL | 6.60 | | 175.5 | | |

Penta Removal Efficiency = [1 - (14/130)] 100 = 89.2%

**Figure 4-9.** Penta In Output Streams

Low Penta Soil Washer Test



Efficiency is 89% (84-92% range), which is very close to the vendor's 90% claim. Using the weighted mass figures, the calculated % Removal Efficiency would be 87.3%. If the % Removal Efficiency is recalculated on the basis of the mass contribution of penta on the Washed Soil to the total penta output mass, the value is increased only to 90.6%.

Since the masses of the input and output streams differ, even on the as-is basis, the mass of penta in each of the output streams must also be considered. In this case, 16.5 mg (9%) of the combined penta mass remains in the Washed Soil (1.18 kg) resulting from processing 1 kg of Feed Soil. The average output penta mass (175.5 mg) is considerably greater (35%) than the input mass (130 mg), perhaps reflecting the previously noted improvement in extractability brought about by the soil washing prior to the analyses.

While it would have been informative to know the distribution of penta in the water and solid phases of a particular output stream, such analyses were not obtained. Approximations of the contributions from solid and liquid phases of a sample can, however, be calculated if one assumes that the associated water is comparable in its penta concentration to that in the CDE (14 mg/L). For example, for the FPC, with a mass of 0.22 kg from 1.0 kg of Feed Soil and containing 30% solids and a weighted average penta concentration of 270 mg/kg, the penta concentration in/on the solids would be:

$$\underbrace{(0.22\text{ kg})(270\text{ mg/kg})}_{\text{fine particle cake}} = \underbrace{(0.22\text{ kg})(0.3)X}_{\text{solid phase}} + \underbrace{[0.22-(0.22)(0.30)](14\text{ mg/L})}_{\text{liquid phase}}$$

$$X = 953\text{ mg/kg}$$

And, reversing the logic, if the CDE contains even 1000 mg/L of suspended solids (650 and 740 mg/L were found in the CDE from the Low and High Penta Soil Washer tests) and these solids contain ~1000 mg/kg of penta, the solids would contribute only 5 mg to the 14 mg/L found.

#### 4.4.2.4 Penta Distribution - High Penta SW Test

Samples of input and output fractions from the High Penta test also were analyzed for penta. Averaged concentration data are presented in Table 4-22 and Figure 4-10. Using the change in concentration from the Feed Soil to the Washed Soil, the average penta Removal Efficiency is 87%, still quite close to the vendor's 90% claim, but with a wide range: 51% to 94%. On the basis of mass, the penta Removal Efficiency decreases to 83.2%.

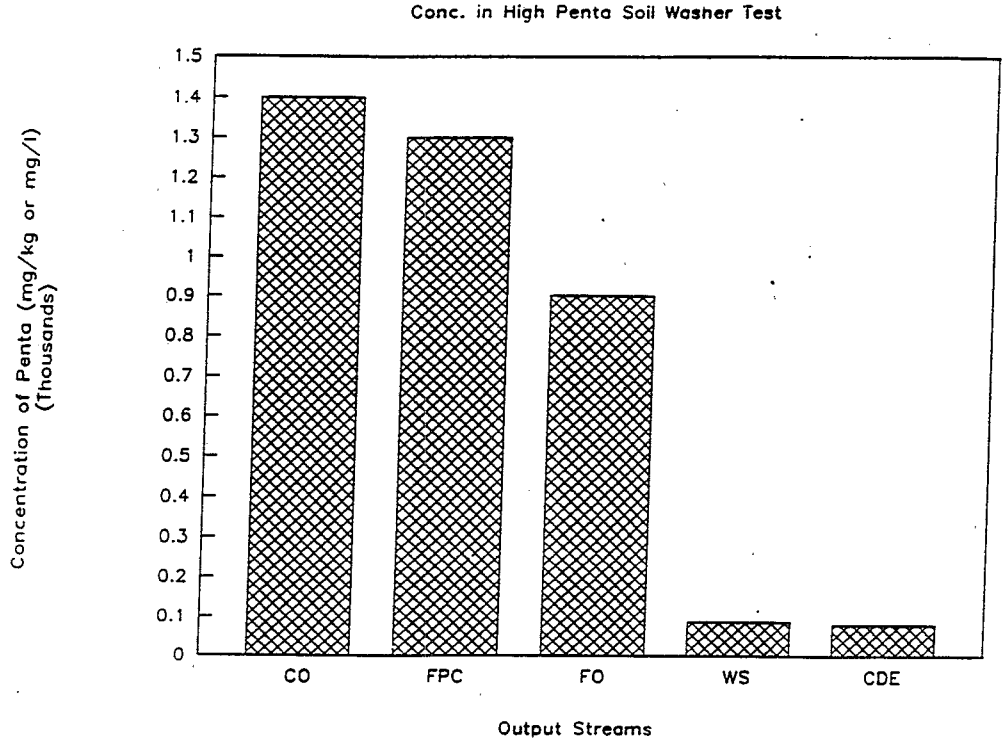
In this case, only 114 mg (11%) of the combined penta output mass is in the Washed Soil (1.31 kg) resulting from processing 1.0 kg of Feed Soil. While the solids balance is reasonable good, the output penta mass (1066 mg) is considerably greater than the input mass (680 mg). If % Removal Efficiency is calculated on the basis of the penta mass contribution in the Washed Soil to the total output penta mass, a value of 89.3% is obtained. Estimated penta concentrations have also been calculated for the solids portion of the output and are also presented in the table.

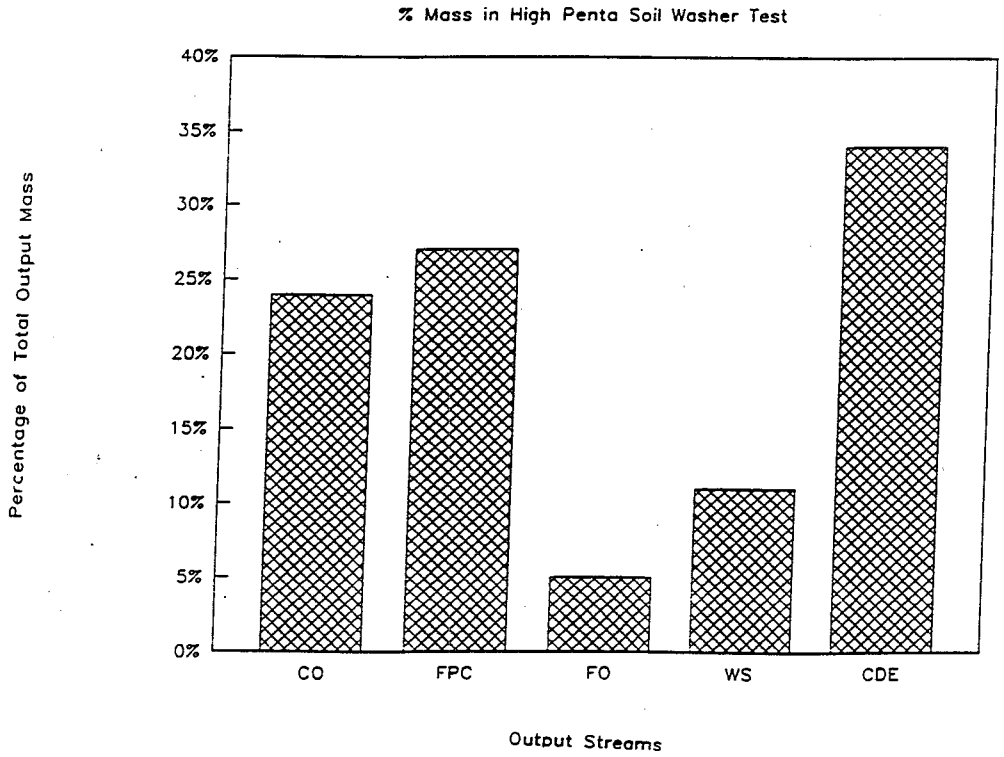
TABLE 4-22. AVERAGE PENTA DISTRIBUTION-HIGH PENTA SOIL WASHER TEST

| INPUT | Stream As Is wt. (Kg) | Conc. (ppm) | Penta Mass (mg) | Dist. (%) | Calc. Conc. on Solids (ppm) |
|---|---|---|---|---|---|
| Feed Soil | 1.00 | 680 | 680 | 98.3 | 790 |
| Municipal Water | 0.22 | 0 | 0 | 0 | --- |
| Thickener Sol'n | 0.75 | 0 | 0 | 0 | --- |
| ATS Effluent | 4.12 | 2.8 | 11.5 | 1.7 | --- |
| TOTAL | 6.09 | | 691.5 | | |
| **OUTPUT** | **Stream As Is wt. (Kg)** | **Conc. (ppm)** | **Penta Mass (mg)** | **Dist. (%)** | **Calc. Conc. on Solids (ppm)** |
| WS | 1.31 | 87 | 114 | 11 | 90 |
| CO | 0.18 | 1400 | 252 | 24 | 2680 |
| FPC | 0.22 | 1300 | 286 | 27 | 3440 |
| FO | 0.06 | 900 | 54 | 5 | 5000 |
| CDE | 4.50 | 80 | 360 | 34 | --- |
| TOTAL | 6.27 | | 1066 | | |

Penta Removal Efficiency = [1 - (87/680)] 100 = 87.2%

**Figure 4-10.** Penta In Output Streams



#### 4.4.2.5 Polynuclear Aromatic Hydrocarbon Distribution

The distribution of PAHs in the individual streams is presented in Tables 4-23 and 4-24 for Low and High Penta tests. Each of these large tables ends with a summary of total PAHs, carcinogenic PAHs and non-carcinogenic PAHs. Based on the results, the highest concentrations and masses of PAHs are found in the FPC while some PAHs are not detected in one or more streams. Using the concentrations and combined masses of PAHs for the Feed Soil and the Washed Soil, % Removal Efficiencies were 83% and 80% in the Low Penta test and 88 and 85% in the High Penta test. Removal Efficiencies for individual PAHs ranged from 45% to 100% in the Low Penta test where detectable and measureable levels were detected in the Washed Soil and 86% to 100% in the High Penta test, where the Washed Soil retained detectable levels of all the PAHs except naphthalene.

Of considerable interest is the observation that the distribution of the masses of total PAHs in the output streams is quite different from that obtained for penta, with much more of the PAH mass in the Fine Particle Cake and much less in the Combined Dewatering Effluent. While concentration data also indicates the same behavior, they fail to take into consideration the mass of the individual output streams. Over 55-60% of the PAHs are concentrated in an output stream that amounts to about 22% of the original Feed Soil mass. This effect probably is a result of the decreased solubility of the PAHs in the water and greater tenacity to the surface of the fine particles. The results, taken from Tables 4-23 and 4-24 and compared with those for penta from Tables 4-21 and 4-22, are summarized in Table 4-25.

The "Total Carcinogenic PAHs" given in Tables 4-23 and 4-24 include those listed below in Column I and derived from Group B2, Probable Human Carcinogens from the National Primary and Secondary Drinking Water Regulations (FR, 55 #143, 30397 [July 25, 1990]). Other PAHs investigated included those in Column II, which are derived from Group D, Insufficient Data to Assess Carcinogenic Potential," and for acenaphthene and acenaphthalene, which are IARC Class 3:

| I | II |
|---|---|
| Benz(a)anthracene --L,H | Acenaphthene --H |
| Benzo(b)fluoranthene --L,H | Acenaphthylene |
| Benzo(k)fluoranthene --H | Anthracene --L,H |
| Benzo(a)pyrene | Fluoranthene |
| Chrysene --L,H | Fluorene --L,H |
| Dibenz(a,h)anthracene | Naphthalene |
| Indeno(1,2,3,-cd)pyrene | Phenanthrene -L,H |
| | Benzo(g,h,i)perylene |
| | Pyrene --L,H |

Those PAHs followed by an "L" or "H" were detected at some quantity in all streams of the Low or High Penta test, respectively.

TABLE 4-23. AVERAGE PAH CONCENTRATION AND MASS
1 Kg FEED SOIL BASIS--LOW PENTA SOIL WASHER TEST

| Soil Washer Stream | Naphthalene | | | Acenaphthylene | | | Acenaphthene | | | Fluorene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | ND | | 0.0 | ND | | 0.0 | 2225 | 4 | 2.2 | 12463 | 8 | 12.5 |
| Municipal Water | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 |
| Total | | | 0.0 | | | 0.0 | | | 2.2 | | | 12.5 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | 6885 | 2 | 8.1 |
| Coarse Oversize | 2033 | 3 | 0.3 | 150 | 1 | 0.0 | 2817 | 6 | 0.4 | 20789 | 9 | 3.0 |
| Fine Particle Cake | ND | | 0.0 | ND | | 0.0 | 6250 | 6 | 1.4 | 38750 | 8 | 8.5 |
| Fine Oversize | 1913 | 4 | 0.1 | ND | | 0.0 | 1065 | 4 | 0.1 | 18500 | 8 | 1.1 |
| Combined Dewatering Effluent | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | 42 | 10 | 0.2 |
| Totals | | | 0.4 | | | 0.0 | | | 1.8 | | | 20.9 |
| Percent Gain or (Loss) | | | NA | | | NA | | | -17% | | | 68% |
| Removal Efficiency | NA | | | NA | | | 100% | | | 45% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-23 (CON'T). PAH COMPOUNDS, LOW PENTA SOIL WASHER TEST

| Soil Washer Stream | Phenanthrene | | | Anthracene | | | Fluoranthene | | | Pyrene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | 30389 | 9 | 30.4 | 136375 | 8 | 136.4 | 17222 | 9 | 17.2 | 27889 | 9 | 27.9 |
| Municipal Water | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 |
| Total | | | 30.4 | | | 136.4 | | | 17.2 | | | 27.9 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | 7680 | 4 | 9.1 | 17083 | 6 | 20.2 | 3100 | 6 | 3.7 | 3450 | 6 | 4.1 |
| Coarse Oversize | 50625 | 8 | 7.4 | 170250 | 4 | 24.8 | 15111 | 9 | 2.2 | 24111 | 9 | 3.5 |
| Fine Particle Cake | 103375 | 8 | 22.6 | 456667 | 3 | 99.6 | 41500 | 8 | 9.1 | 69250 | 8 | 15.1 |
| Fine Oversize | 42857 | 7 | 2.5 | 106000 | 4 | 6.3 | 10663 | 8 | 0.6 | 13463 | 8 | 0.8 |
| Combined Dewatering Effluent | 70 | 9 | 0.4 | 280 | 11 | 1.5 | 22 | 9 | 0.1 | 33 | 10 | 0.2 |
| Totals | | | 41.9 | | | 152.3 | | | 15.7 | | | 23.7 |
| Percent Gain or (Loss) | | | 38% | | | 12% | | | -9% | | | -15% |
| Removal Efficiency | 75% | | | 87% | | | 82% | | | 88% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-23 (CON'T). PAH COMPOUNDS, LOW PENTA SOIL WASHER TEST

| Soil Washer Stream | Benzo(a)anthracene | | | Chrysene | | | Benzo(b)fluoranthene | | | Benzo(K)fluoranthene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | 3950 | 8 | 4.0 | 11450 | 8 | 11.5 | 2425 | 4 | 2.4 | 1500 | 1 | 1.5 |
| Municipal Water | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 |
| Total | | | 4.0 | | | 11.5 | | | 2.4 | | | 1.5 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | 817 | 3 | 1.0 | 2210 | 4 | 2.6 | 870 | 1 | 1.0 | ND | | 0.0 |
| Coarse Oversize | 3700 | 7 | 0.5 | 9089 | 9 | 1.3 | 1850 | 4 | 0.3 | 1300 | 3 | 0.2 |
| Fine Particle Cake | 13025 | 8 | 2.8 | 30125 | 8 | 6.6 | 6720 | 5 | 1.5 | 7350 | 6 | 1.6 |
| Fine Oversize | 2438 | 8 | 0.1 | 6375 | 8 | 0.4 | 1783 | 6 | 0.1 | 817 | 3 | 0.0 |
| Combined Dewatering Effluent | 18 | 3 | 0.1 | 18 | 4 | 0.1 | ND | | 0.0 | ND | | 0.0 |
| Totals | | | 4.6 | | | 11.0 | | | 2.9 | | | 1.8 |
| Percent Gain or (Loss) | | | 16% | | | -4% | | | 18% | | | 23% |
| Removal Efficiency | 79% | | | 81% | | | 64% | | | 100% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-23 (CON'T). PAH COMPOUNDS, LOW PENTA SOIL WASHER TEST

| Soil Washer Stream | Benzo(a)pyrene | | | Benzo(g,h,i)perylene | | | Total PAHs | | Carcinogenic PAHs | | Non-Carcinogenic PAHs | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | No. of Samples | Mass (mg) | Mean Conc. (ppb) | Mass (mg) | Mean Conc. (ppb) | Mass (mg) | Mean Conc. (ppb) | Mass (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | 1100 | 1 | 1.1 | ND | | 0.0 | 246988 | 247.0 | 20425 | 20.4 | 226563 | 226.6 |
| Municipal Water | ND | | 0.0 | ND | | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Total | | | 1.1 | | | 0.0 | | 247.0 | | 20.4 | | 226.6 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | ND | | 0.0 | ND | | 0.0 | 42095 | 49.7 | 3897 | 4.6 | 38198 | 45.1 |
| Coarse Oversize | 2133 | 3 | 0.3 | 4700 | 2 | 0.7 | 308658 | 44.9 | 18072 | 2.6 | 290586 | 42.3 |
| Fine Particle Cake | 4800 | 1 | 1.0 | ND | | 0.0 | 777812 | 169.7 | 62020 | 13.5 | 715792 | 156.2 |
| Fine Oversize | 928 | 4 | 0.1 | 1100 | 1 | 0.1 | 207900 | 12.3 | 12340 | 0.7 | 195560 | 11.6 |
| Combined Dewatering Effluent | ND | | 0.0 | ND | | 0.0 | 483 | 2.5 | 36 | 0.2 | 448 | 2.3 |
| Totals | | | 1.4 | | | 0.7 | | 279.1 | | 21.7 | | 257.5 |
| Percent Gain or (Loss) | | | 28% | | | NA | | 13% | | 6% | | 14% |
| Removal Efficiency | 100% | | | NA | | | 83% | | 81% | | 83% | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-24. AVERAGE PAH COMPOUND CONCENTRATION AND MASS
ONE KILOGRAM FEED SOIL BASIS, HIGH PENTA SOIL WASHER TEST

| Soil Washer Stream | Naphthalene | | | Acenaphthylene | | | Acenaphthene | | | Fluorene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | ND | | 0 | 1300 | 1 | 1.3 | 21000 | 20 | 21 | 24000 | 16 | 24 |
| Municipal Water | ND | | 0 | ND | | 0 | ND | | 0 | ND | | 0 |
| ATS Treated Water | ND | | 0 | ND | | 0 | ND | | 0 | ND | | 0 |
| Totals | | | 0.0 | | | 1.3 | | | 21.0 | | | 24.0 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | ND | | 0.0 | ND | | 0.0 | 2400 | 11 | 3.1 | 2700 | 10 | 3.5 |
| Coarse Oversize | 1300 | 1 | 0.2 | ND | | 0.0 | 28000 | 16 | 4.8 | 31000 | 12 | 5.3 |
| Fine Particle Cake | 4800 | 2 | 1.0 | ND | | 0.0 | 54000 | 19 | 11.7 | 59000 | 17 | 12.8 |
| Fine Oversize | 2600 | 3 | 0.1 | ND | | 0.0 | 25000 | 21 | 1.4 | 28000 | 18 | 1.6 |
| Combined Dewatering Effluent | 26 | 3 | 0.1 | 36 | 1 | 0.2 | 110 | 20 | 0.5 | 110 | 11 | 0.5 |
| Totals | | | 1.5 | | | 0.2 | | | 21.5 | | | 23.6 |
| Percent Gain or (Loss) | | | N/A | | | -87% | | | 2% | | | -2% |
| Removal Efficiency | N/A | | | 100% | | | 89% | | | 89% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-24 (CON'T). PAH COMPOUNDS, HIGH PENTA SOIL WASHER TEST

| Soil Washer Stream | Phenanthrene | | | Anthracene | | | Fluoranthene | | | Pyrene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | 80000 | 19 | 80 | 46000 | 19 | 46 | 69000 | 19 | 69 | 74000 | 20 | 74 |
| Municipal Water | ND | | 0 | ND | | 0 | ND | | 0 | ND | | 0 |
| ATS Treated Water | ND | | 0 | ND | | 0 | 110 | 1 | 0.5 | 110 | 1 | 0.5 |
| Totals | | | 80.0 | | | 46.0 | | | 69.5 | | | 74.5 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | 10000 | 19 | 12.8 | 4700 | 19 | 6.0 | 9800 | 19 | 12.5 | 9300 | 19 | 11.9 |
| Coarse Oversize | 99000 | 11 | 17.1 | 70000 | 16 | 12.1 | 97000 | 13 | 16.7 | 95000 | 17 | 16.4 |
| Fine Particle Cake | 230000 | 14 | 49.8 | 104000 | 19 | 22.5 | 210000 | 14 | 45.5 | 179000 | 15 | 38.8 |
| Fine Oversize | 82000 | 11 | 4.6 | 60000 | 17 | 3.3 | 72000 | 11 | 4.0 | 85000 | 21 | 4.7 |
| Combined Dewatering Effluent | 370 | 17 | 1.7 | 170 | 21 | 0.8 | 370 | 22 | 1.7 | 310 | 22 | 1.4 |
| Totals | | | 85.9 | | | 44.7 | | | 80.4 | | | 73.2 |
| Percent Gain or (Loss) | | | 7% | | | -3% | | | 16% | | | -2% |
| Removal Efficiency | 88% | | | 90% | | | 86% | | | 87% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-24 (CON'T). PAH COMPOUNDS, HIGH PENTA SOIL WASHER TEST

| Soil Washer Stream | Benzo(a)anthracene | | | Chrysene | | | Benzo(b)fluoranthene | | | Benzo(k)fluoranthene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | 17000 | 20 | 17 | 30000 | 20 | 30 | 13000 | 14 | 13 | 11000 | 11 | 11 |
| Municipal Water | ND | | 0 | ND | | 0 | ND | | 0 | ND | | 0 |
| ATS Treated Water | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 |
| Totals | | | 17.0 | | | 30.0 | | | 13.0 | | | 11.0 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | 2200 | 12 | 2.8 | 3800 | 15 | 4.9 | 1400 | 6 | 1.8 | 1500 | 5 | 1.9 |
| Coarse Oversize | 27000 | 17 | 4.7 | 42000 | 17 | 7.2 | 14000 | 16 | 2.4 | 13000 | 9 | 2.2 |
| Fine Particle Cake | 47000 | 19 | 10.2 | 75000 | 19 | 16.3 | 31000 | 19 | 6.7 | 26000 | 13 | 5.6 |
| Fine Oversize | 22000 | 21 | 1.2 | 40000 | 21 | 2.2 | 13000 | 21 | 0.7 | 11000 | 21 | 0.6 |
| Combined Dewatering Effluent | 78 | 21 | 0.4 | 120 | 21 | 0.5 | 51 | 15 | 0.2 | 45 | 12 | 0.2 |
| Totals | | | 19.2 | | | 31.1 | | | 11.9 | | | 10.6 |
| Percent Gain or (Loss) | | | 13% | | | 4% | | | -9% | | | -4% |
| Removal Efficiency | 87% | | | 87% | | | 89% | | | 86% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-24 (CON'T). PAH COMPOUNDS, HIGH PENTA SOIL WASHER TEST

| Soil Washer Stream | Benzo(a)pyrene | | | Indeno(1,2,3-cd)pyrene | | | Dibenz(a,h)anthracene | | | Benzo(g,h,I)perylene | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) | Mean Conc. (ppb) | No. of Samples | (mg) |
| Inputs: | | | | | | | | | | | | |
| Feed Soil | 8200 | 10 | 8.2 | 3800 | 3 | 3.8 | 1700 | 3 | 1.7 | 4100 | 2 | 4.1 |
| Municipal Water | ND | | 0 | ND | | 0 | ND | | 0 | ND | | 0 |
| ATS Treated Water | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 |
| Totals | | | 8.2 | | | 3.8 | | | 1.7 | | | 4.1 |
| Outputs: | | | | | | | | | | | | |
| Washed Soil | 550 | 2 | 0.7 | ND | | 0.0 | ND | | 0.0 | ND | | 0.0 |
| Coarse Oversize | 8200 | 15 | 1.4 | 4000 | 4 | 0.7 | 1400 | 4 | 0.2 | 4400 | 3 | 0.8 |
| Fine Particle Cake | 19000 | 18 | 4.1 | 15000 | 1 | 3.3 | 1900 | 1 | 0.4 | 8300 | 2 | 1.8 |
| Fine Oversize | 9800 | 21 | 0.5 | 6200 | 21 | 0.3 | 2300 | 8 | 0.1 | 4600 | 8 | 0.3 |
| Combined Dewatering Effluent | 49 | 6 | 0.2 | 45 | 1 | 0.2 | ND | | 0.0 | ND | | 0.0 |
| Totals | | | 7.0 | | | 4.5 | | | 0.8 | | | 2.8 |
| Percent Gain or (Loss) | | | -15% | | | 18% | | | -54% | | | -31% |
| Removal Efficiency | 93% | | | 100% | | | 100% | | | 100% | | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-24 (CON'T). PAH COMPOUNDS, HIGH PENTA
SOIL WASHER TEST

| Soil Washer Stream | Total PAHs | | Carcinogenic PAHs | | Non-Carcinogenic PAHs | |
|---|---|---|---|---|---|---|
| | Mean Conc. (ppb) | (mg) | Mean Conc. (ppb) | (mg) | Mean Conc. (ppb) | (mg) |
| Inputs: | | | | | | |
| Feed Soil | 404100 | 404.1 | 71000 | 71 | 333100 | 333.1 |
| Municipal Water | 0 | 0 | 0 | 0 | 0 | 0 |
| ATS Treated Water | 220 | 0.9 | 0 | 0.0 | 220 | 0.9 |
| Totals | | 405.0 | | 71.0 | | 334.0 |
| Outputs: | | | | | | |
| Washed Soil | 48350 | 61.8 | 8900 | 11.4 | 39450 | 50.4 |
| Coarse Oversize | 535300 | 92.2 | 96000 | 16.5 | 439300 | 75.7 |
| Fine Particle Cake | 1064000 | 230.5 | 179000 | 38.8 | 885000 | 191.8 |
| Fine Oversize | 463500 | 25.8 | 86000 | 4.8 | 377500 | 21.0 |
| Combined Dewatering Effluent | 1890 | 8.6 | 294 | 1.3 | 1596 | 7.3 |
| Totals | | 418.9 | | 72.8 | | 346.1 |
| Percent Gain or (Loss) | | 3% | | 3% | | 4% |
| Removal Efficiency | 88% | | 87% | | 88% | |

ND = Not Detected
N/A = Not Applicable

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TABLE 4-25. COMPARISON OF PENTA AND PAH DISTRIBUTION IN OUTPUT STREAMS FROM SOIL WASHING TESTS

| output stream | Low Penta test | | High Penta test | |
|---|---|---|---|---|
| | PAHs %[1] | Penta %[1] | PAHs %[1] | Penta %[1] |
| Coarse Oversize | 16.1 | 13.6 | 22.0 | 23.6 |
| Fine Particle Cake | 60.8 | 33.8 | 55.0 | 26.8 |
| Fine Oversize | 4.4 | 3.3 | 6.2 | 5.1 |
| Washed Soil | 17.8 | 9.4 | 14.8 | 10.7 |
| Combined Dewater. Effl. | 0.9 | 39.9 | 2.0 | 33.8 |

[1]Based on 100 x $\frac{\text{mass in output fraction}}{\text{total output mass}}$

The Removal Efficiency for Total Carcinogenic PAHs in the Low Penta and the High Penta Soil Washer tests, respectively, were 83% and 88%, based on differences in total concentrations between Feed Soil and Washed Soil.

#### 4.4.2.6 Total Organic Carbon and Total Recoverable Petroleum Hydrocarbons

The average TOC removal efficiency for the Low Penta Soil Washer Test was 84% (Feed Soil: 12,000 mg/kg; Washed Soil: 1,900 mg/kg) with a range of 57% to 93%. In the High Penta test, the TOC removal efficiency was 81% (Feed Soil: 17,000 mg/kg; Washed Soil: 3,200 mg/kg) with a range from -21% to 99%. The high TOC values probably reflect the presence of woody material and the carrier oil used in penta treatment of wood. In both tests, the wide range suggests that the average removal efficiency is only useful in a very general sense. The data are provided in Volume II.

The mean TRPH removal efficiency in the Low Penta Soil Washer test was 94% (Feed Soil: 3,800 mg/kg; Washed Soil: 210 mg/kg) with a range of 89% to 98%. In the High Penta test, the efficiency was 92% (Feed Soil: 8,900 mg/kg; Washed Soil: 690 mg/kg) with a range of 41% to 98%. The data are provided in Volume II.

#### 4.4.2.7 Metals Behavior

Chromium, copper, arsenic -- Average results for the Low and High Penta Soil Washer tests are summarized in Table 4-26 and 4-27 and Figures 4-11 and 4-12. Using the same 1 kg of as-is Feed Soil basis, the average mass for each metal in each process stream was calculated by multiplying the average measured (or estimated) concentration (see Volume II for the individual data and statistical analyses) for each metal by the corresponding process stream mass. In both the Low and High Penta tests, the metals are quite consistently distributed, with the Fine Particle Cake containing the highest concentration and mass of each metal. On a concentration basis, Coarse Oversize was the next largest contributor, but on a mass content the Washed Soil was either equal to or greater than the Coarse Oversize, as noted below:

TABLE 4-26. AVERAGE METALS BALANCE – LOW PENTA SW TEST

| | stream kg as-is | Arsenic ppm | mg | % of total | Chromium ppm | mg | % of total | Copper ppm | mg | % of total | Barium ppm | mg | % of total | Lead ppm | mg | % of total | Mercury ppm | mg | % of total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INPUT | | | | | | | | | | | | | | | | | | | |
| Feed Soil | 1.00 | 13.50 | 13.50 | 100 | 17.00 | 17.00 | 100 | 14.70 | 14.70 | 95 | | no info | | | no info | | | no info | |
| Municipal Water | 5.45 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.15 | 0.82 | 5 | | | | | | | | | |
| Thickener Soln | 0.82 | | 0.00 | 0 | | 0.00 | 0 | | 0.00 | 0 | | | | | | | | | |
| ATS Effluent | 0.00 | | 0.00 | 0 | | 0.00 | 0 | | 0.00 | 0 | | | | | | | | | |
| TOTAL | 7.27 | | 13.50 | 100 | | 17.00 | 100 | | 15.52 | 100 | | | | | | | | | |
| OUTPUT | | | | | | | | | | | | | | | | | | | |
| Washed Soil | 1.18 | 5.00 | 5.90 | 31 | 8.80 | 10.38 | 40 | 5.60 | 6.61 | 29 | 13.50 | 15.93 | 24 | 5.00 | 5.90 | 23 | 0.10 | 0.12 | 73 |
| Coarse Oversize | 0.14 | 23.60 | 3.30 | 18 | 28.70 | 4.02 | 16 | 30.00 | 4.20 | 19 | 236.50 | 33.11 | 49 | 16.20 | 2.27 | 9 | 0.00 | 0.00 | 0 |
| Fine Particle Cake | 0.22 | 41.20 | 9.06 | 48 | 48.00 | 10.56 | 41 | 49.40 | 10.87 | 48 | 80.30 | 17.67 | 26 | 75.70 | 16.65 | 65 | 0.20 | 0.04 | 27 |
| Fine Oversize | 0.06 | 5.70 | 0.34 | 2 | 9.70 | 0.58 | 2 | 11.80 | 0.71 | 3 | 6.70 | 0.40 | 1 | 11.30 | 0.68 | 3 | 0.00 | 0.00 | 0 |
| Combined Dewater Eff | 5.00 | 0.03 | 0.15 | 1 | 0.03 | 0.15 | 1 | 0.04 | 0.20 | 1 | 0.12 | 0.60 | 1 | 0.05 | 0.25 | 1 | 0.00 | 0.00 | 0 |
| TOTAL | 6.60 | | 18.76 | 100 | | 25.69 | 100 | | 22.58 | 100 | | 67.71 | 100 | | 25.75 | 100 | | 0.16 | 100 |
| % Removal Efficiency | | 63.0 | 56.3 | | 48.2 | | | 61.9 | | | — | | | — | | | — | | |

file: 4-24

TABLE 4-27. AVERAGE METALS BALANCE – HIGH PENTA SW TEST

| | stream kg as-is | Arsenic ppm | mg | % of total | Chromium ppm | mg | % of total | Copper ppm | mg | % of total | Barium ppm | mg | % of total | Lead ppm | mg | % of total | Mercury ppm | mg | % of total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INPUT | | | | | | | | | | | | | | | | | | | |
| Feed Soil | 1.00 | 31.40 | 31.40 | 99 | 38.50 | 38.50 | 100 | 33.80 | 33.80 | 100 | | 0.00 | 0 | | no info | | | no info | |
| Municipal Water | 0.22 | 0.01 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.03 | 0.01 | 0 | 0.07 | 0.02 | 100 | | | | | | |
| Thickener Soln | 0.75 | | 0.00 | 0 | | 0.00 | 0 | | 0.00 | 0 | | 0.00 | 0 | | | | | | |
| ATS Effluent | 4.12 | 0.04 | 0.16 | 1 | 0.01 | 0.04 | 0 | 0.02 | 0.08 | 0 | | 0.00 | 0 | | | | | | |
| TOTAL | 6.09 | | 31.57 | 100 | | 38.54 | 100 | | 33.89 | 100 | | 0.02 | 100 | | | | | | |
| OUTPUT | | | | | | | | | | | | | | | | | | | |
| Washed Soil | 1.31 | 11.60 | 15.20 | 31 | 14.00 | 18.34 | 27 | 10.10 | 13.23 | 24 | 23.15 | 30.33 | 31 | 6.83 | 8.95 | 34 | 0.10 | 0.13 | 64 |
| Coarse Oversize | 0.18 | 64.10 | 11.54 | 24 | 105.60 | 19.01 | 28 | 63.20 | 11.38 | 21 | 256.60 | 46.19 | 47 | 21.40 | 3.85 | 15 | 0.10 | 0.02 | 9 |
| Fine Particle Cake | 0.22 | 88.00 | 19.36 | 40 | 123.60 | 27.19 | 40 | 123.10 | 27.08 | 50 | 87.50 | 19.25 | 20 | 46.90 | 10.32 | 40 | 0.20 | 0.04 | 21 |
| Fine Oversize | 0.06 | 20.50 | 1.23 | 3 | 36.20 | 2.17 | 3 | 26.30 | 1.58 | 3 | 15.80 | 0.95 | 1 | 11.10 | 0.67 | 3 | 0.20 | 0.01 | 6 |
| Combined Dewater Eff | 4.50 | 0.22 | 0.99 | 2 | 0.20 | 0.90 | 1 | 0.29 | 1.31 | 2 | 0.39 | 1.76 | 2 | 0.50 | 2.25 | 9 | 0.00 | 0.00 | 0 |
| TOTAL | 6.27 | | 48.31 | 100 | | 67.61 | 100 | | 54.57 | 100 | | 98.47 | 100 | | 26.03 | 100 | | 0.21 | 100 |
| % Removal Efficiency | | 63.1 | 51.6 | | 63.6 | 52.4 | | 70.1 | 60.9 | | — | — | | — | — | | — | — | |

file: 4-25

FIGURE 4-11. EFFLUENT METALS IN BIOTROL SOIL WASHER LOW PENTA SW TEST

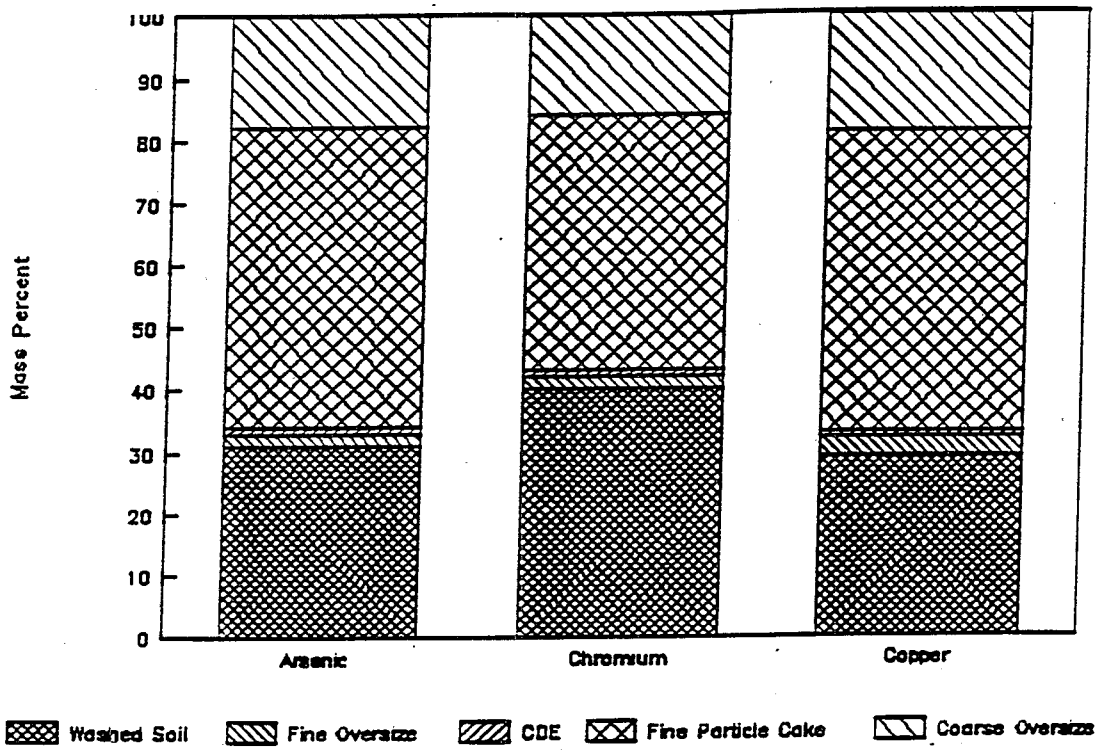
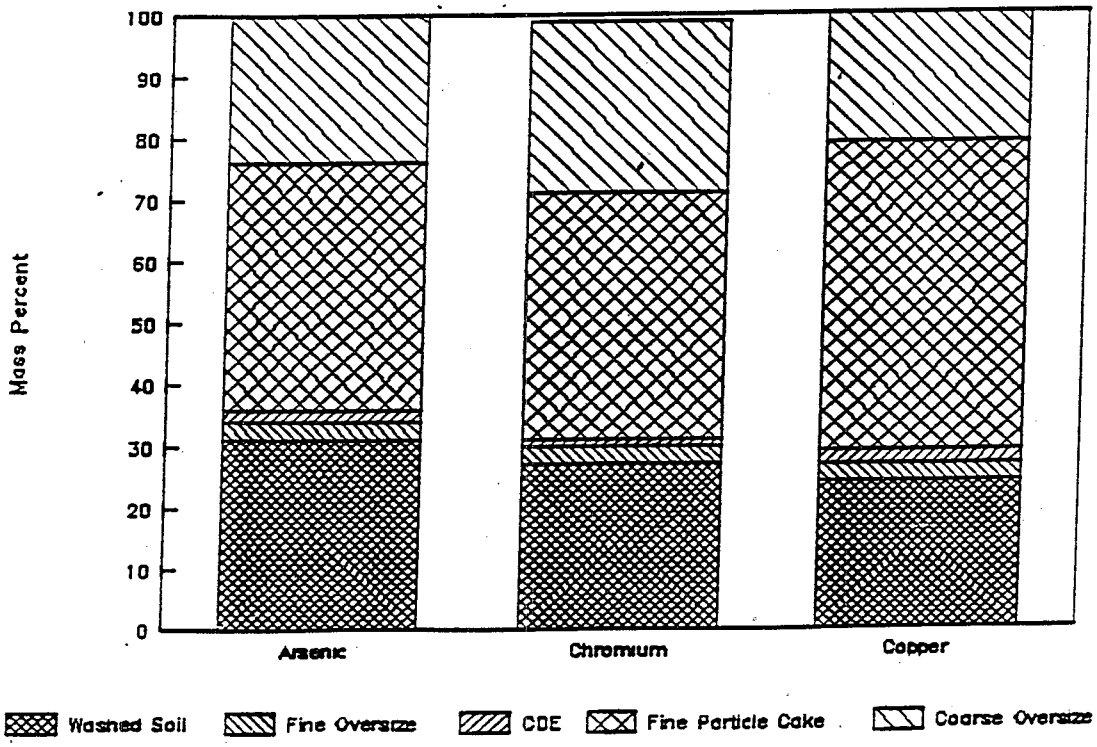



FIGURE 4-12. EFFLUENT METALS IN BIOTROL SOIL WASHER HIGH PENTA SW TEST



conc: FPC > CO > FO > WS > CDE

mass: FPC > WS ≥ CO > FO > CDE

Large discrepancies between influent and effluent masses for both tests may reflect the high variations in the original analyses (i.e., high standard deviations) or may, as noted earlier, reflect improved accessibility of metals for analysis in product streams. Removal efficiencies (based on metal masses in the Washed Soil compared to those in 1.0 kg of the Feed Soil) in the Low Penta test were: As: 56%; Cr: 39%; and Cu: 55%. In the High Penta test, the comparable removals were: As: 52%; Cr: 52%; and Cu: 61%.

Other Metals -- Other metals were also analyzed in the various influent and effluent streams (also reported in Table 4-26 and 4-27). The number of samples was limited and there were large variations in relative standard deviations. Therefore, only general trends should be discussed. Low concentrations of lead were found and appeared to follow the same distribution as the other metals. Barium was consistently encountered, and appeared to be distributed differently in the output streams,with the Coarse Oversize containing about half of the mass of barium in both Low and High Penta tests. The source of these metals is unknown. Cadmium, selenium, and silver were either not detected or found in very low concentrations in any process streams.

EP Toxicity -- Tables 4-28 and 4-29 summarize the EP Toxicity test results of output streams for the Low Penta and the High Penta Soil Washer tests, respectively. Only chromium and copper were detected in the Low Penta test in about equal concentrations in the Fine Particle Cake, Coarse Oversize, and Fine Oversize. In the High Penta SW test, arsenic, chromium and copper were found, primarily in the leachate from the Fine Particle Cake, with lower concentrations in the leachates from the Fine Oversize and Washed Soil. No cadmium, lead, mercury, selenium, or silver was detected in either test. Barium was present in every process stream with the Washed Soil and the Fine Oversize being the largest sources in both SW tests. Unfortunately, there are no EP Toxicity Test data for the Feed Soils for comparison. Since barium is not commonly used in the wood preserving industry, there is no explanation for its presence.

#### 4.4.2.8 Flow Rate Stability

Low Penta SW Material Flow Rates -- The Feed Soil rate planned for the Low Penta SW study was approximately 275 kg/hr (610 lbs/hr) on an as-is weight basis. In fact, the Soil Washer operated for the first 28 hours of the test at 250 to 300 kg/hr (550 to 660 lbs/hr). Starting at hour 28, clogging, caused by Feed Soil compaction at the base of the hopper, impeded the transfer of soil to the feed conveyor. Efforts to eliminate the problem were unsuccessful. This resulted in a sharp decline in the Feed Soil rate to about 125 kg/hr (280 lbs/hr), or 45% of planned operation. For the entire test the average Feed Soil rate was 220 kg/hr.

Washed Soil output rate closely followed the fluctuations in the Feed Soil rate. This suggests that retention time within the Soil Washer did not produce a significant response lag. The Washed Soil output rate was consistently greater than the Feed Soil input rate because of water uptake during the soil washing process. The minor solids output streams -- Coarse Oversize, Fine

TABLE 4-28. EP TOXICITY TEST RESULTS - LOW PENTA SW TEST
(ug/L)

| Process Stream | Sample-ID Test Day-Time Period | Arsenic | Barium | Cadmium | Chromium | Copper | Lead | Mercury | Selenium | Silver |
|---|---|---|---|---|---|---|---|---|---|---|
| Washed Soil | SWL-WS-01-03 | < 100.0 | 522.0 | < 5.0 | 10.3 | NA | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | SWL-WS-02-03 | < 100.0 | 553.0 | < 5.0 | 10.9 | < 10.0 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | Average | | 538 | | 11 | | | | | |
| | Standard Deviation | | 22 | | 0 | | | | | |
| Coarse Oversize | SWL-CO-01-03 | < 100.0 | 148.0 | < 5.00 | 15.0 | 16.0 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | SWL-CO-02-03 | < 100.0 | 201.0 | < 5.00 | 13.6 | 314.0 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | Average | | 175 | | 14 | 165 | | | | |
| | Standard Deviation | | 37 | | 1 | 211 | | | | |
| Fine Oversize | SWL-F0-01-03 | < 100.0 | 420.0 | < 5.0 | 13.2 | 13.0 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | SWL-F0-02-03 | < 100.0 | 469.0 | < 5.0 | 15.1 | 13.2 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | Average | | 445 | | 14 | 13 | | | | |
| | Standard Deviation | | 35 | | 1 | 0 | | | | |
| Fine Particle Cake | SWL-FPC-01-03+ | < 100.0 | 314.0 | < 5.00 | 14.7 | 10.9 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | SWL-FPC-02-03 | < 100.0 | 434.0 | < 5.00 | 12.0 | 12.3 | < 50.0 | < 0.20 | < 200.0 | < 10.0 |
| | Average | | 374 | | 13 | 12 | | | | |
| | Standard Deviation | | 85 | | 2 | 1 | | | | |

+ Archive sample
filename: TAB4-28.WK1

TABLE 4-29. EP TOXICITY TEST RESULTS - HIGH PENTA SW TEST
(UG/L)

| Process Stream | Sample-ID Test Day-Time Period | Arsenic | Barium | Cadmium | Chromium | Copper | Lead | Mercury | Selenium | Silver |
|---|---|---|---|---|---|---|---|---|---|---|
| Washed Soil | SWH-WS-01-01 | < 100.0 | 69.2 | < 5.0 | 14.7 | 26.1 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-WS-02-01 | < 100.0 | 439.0 | < 5.0 | < 10.0 | 17.8 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-WS-04-01 | < 100.0 | 301.0 | < 5.0 | < 10.0 | 11.7 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-WS-05-01 | < 100.0 | 449.0 | < 5.0 | < 10.0 | 23.0 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-WS-06-01 | < 100.0 | 312.0 | < 5.0 | < 10.0 | 10.8 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | Average | | 314 | | 15 | 18 | | | | |
| | Standard Deviation | | 153 | | 0 | 7 | | | | |
| Coarse Oversize | SWH-CO-01-01 | < 100.0 | 83.6 | < 5.0 | < 10.0 | 18.9 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-CO-02-01 | < 100.0 | 169.0 | < 5.0 | 18.3 | 50.7 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-CO-04-01 | < 100.0 | 123.0 | < 5.0 | < 10.0 | 28.1 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-CO-05-01 | < 100.0 | 461.0 | < 5.0 | < 10.0 | 36.2 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-CO-06-01 | < 100.0 | 121.0 | < 5.0 | < 10.0 | 31.5 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | Average | | 192 | | 18 | 33 | | | | |
| | Standard Deviation | | 154 | | 0 | 12 | | | | |
| Fine Oversize | SWH-FO-01-01 | < 100.0 | 348.0 | < 5.0 | < 10.0 | 23.2 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FO-02-01 | < 100.0 | 423.0 | < 5.0 | 22.0 | 37.1 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FO-04-01 | 120.0 | 252.0 | < 5.0 | 11.9 | 29.0 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FO-05-01 | 130.0 | 359.0 | < 5.0 | < 10.0 | 29.8 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FO-06-01 | 139.0 | 311.0 | < 5.0 | 11.9 | 39.5 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | Average | 130 | 339 | | 15 | 32 | | | | |
| | Standard Deviation | 10 | 63 | | 6 | 7 | | | | |
| Fine Particle Cake | SWH-FPC-01-01 | 214.0 | 272.0 | < 5.0 | 22.6 | 60.9 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FPC-02-01 | 219.0 | 220.0 | < 5.0 | 19.6 | 47.6 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FPC-04-01 | 148.0 | 120.0 | < 5.0 | < 10.0 | 27.8 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FPC-05-01 | 174.0 | 207.0 | < 5.0 | < 10.0 | 47.1 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | SWH-FPC-05-01 | 174.0 | 207.0 | < 5.0 | < 10.0 | 47.1 | < 50.0 | < 0.2 | < 200.0 | < 10.0 |
| | Average | 186 | 205 | | 21 | 46 | | | | |
| | Standard Deviation | 30 | 55 | | 2 | 12 | | | | |

filename: TAB4-29.WK1

Oversize, and Fine Particle Cake -- also reflected variations in Feed Soil rates but to a lesser extent. Flow rates are graphically summarized in Figure 4-13.

Municipal Water (MW) was the primary aqueous input stream, averaging 20 liters per minute (5.3 gpm) after a few initial adjustments (through hour 10), while the Cationic Polymer input stream (Floc) contributed a steady but minor flow rate of 2.7 liters per minute (0.7 gpm). Aqueous flow rates are shown graphically in Figure 4-14.

The Combined Dewatering Effluent flow rate closely followed fluctuations in the Municipal Water input rate, again suggesting that retention time did not create a significant response lag. The Combined Dewatering Effluent flow rate was approximately equal to the Municipal Water input rate because the Cationic Polymer input stream offset water uptake by the solids-bearing output streams.

High Penta SW Material Flow Rates -- In this test the Feed Soil rate was stable between 140 and 150 kg/hr (310 and 330 lbs/hr) for the first 40 hours until mechanical problems (compaction) with the feed system forced operation at a reduced rate for about 10 hours. After the scheduled break to deliver Fine Particle Slurry to the Slurry Bio-Reactor (hours 50 to 80), a vibrating device was attached to the outside of the feed hopper and corrected the soil compaction problem. Feed Soil flow rate increased by 50 kg/hr (110 lbs/hr) to approximately 200 kg/hr (440 lbs/hr). The unit operated at this level for 30 hours. During hours 110 to 150 intermittent mechanical failures again destabilized the feed delivery system and caused a drop in the Feed Soil rate.

The Washed Soil flow rate closely reflected changes in the Feed Soil rate, as during the Low Penta test. However, the difference between the two flow rates was greater, reflecting the higher moisture in the Washed Soil during this test. The smaller output solids streams behaved as in the Low Penta test.

Treated effluent from the BioTrol Aqueous Treatment System was the primary aqueous input stream, averaging 11 liters per minute (2.9 gpm). However, treated water flow rate never stabilized during the test, starting at about 14 liters per minute (3.7 gpm) and gradually decreased to 7 liters per minute (1.9 gpm). Municipal Water supplied 1 to 3 liters per minute (0.3 to 0.8 gpm) during the first 90 hours of operation after which it was used only intermittently; over the course of the test this source provided an average of 0.6 liters per minute (0.2 gpm). The Cationic Polymer flow rate was, once again, constant throughout the test at about 2 liters/minute (0.5 gpm).

Figures 4-15 and 4-16 summarize the flow rate behavior of the various input and output streams during the High Penta SW test.

Feed Soil Flow Rate Effects on Organic Contaminant Removal -- As noted earlier, during the Low Penta SW test the Soil Washer experienced a significant drop in Feed Soil input rate. Analysis of the data presented in Table 4-30, which are summarized graphically in Figure 4-17, suggests that:

(1) penta concentration in the Washed Soil was not affected by the drop in Feed Soil flow rate during the Low Penta SW Test; and

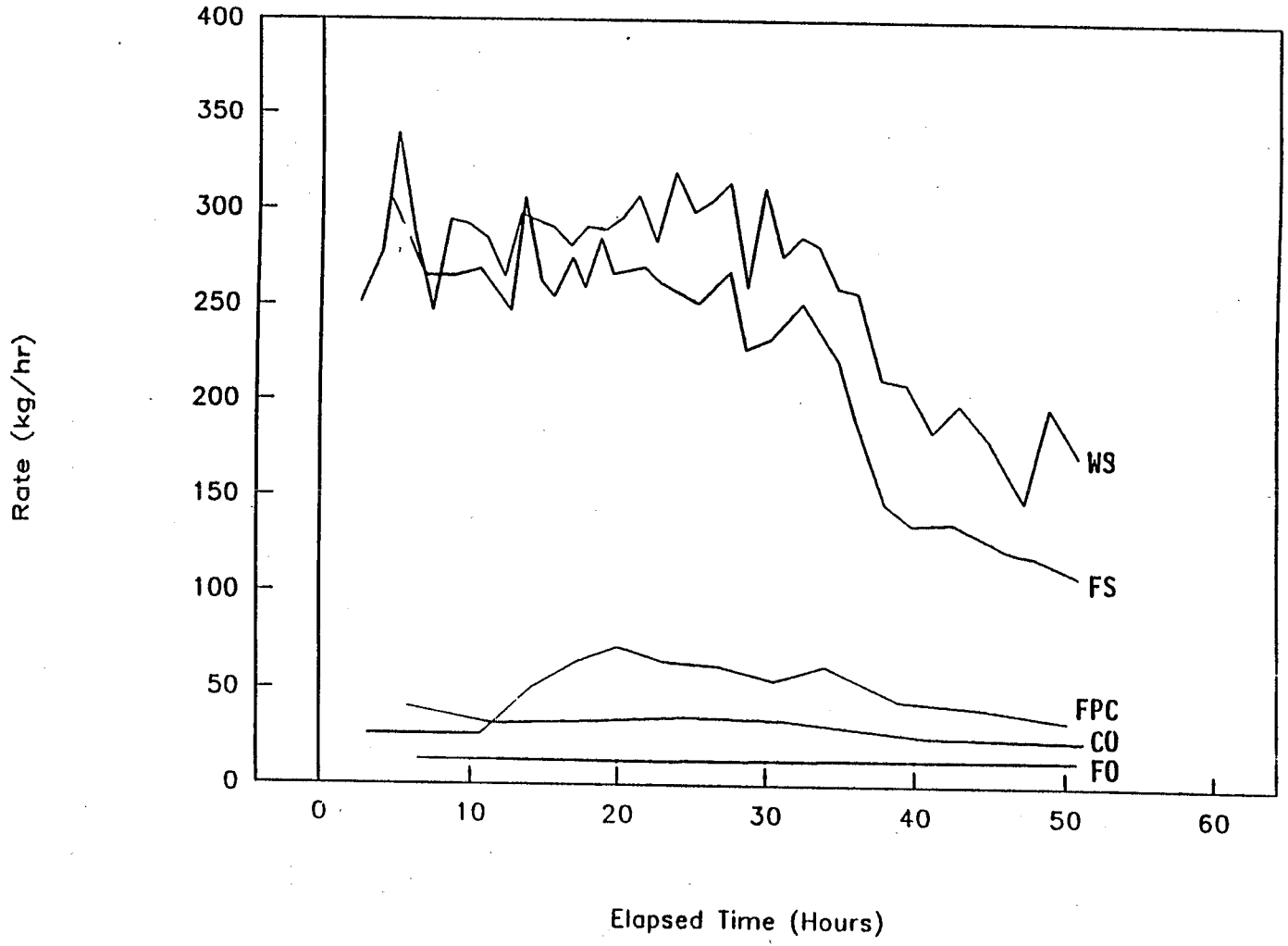



Figure 4-13. Solids Stream Flows - Low Penta Soil Washer Test

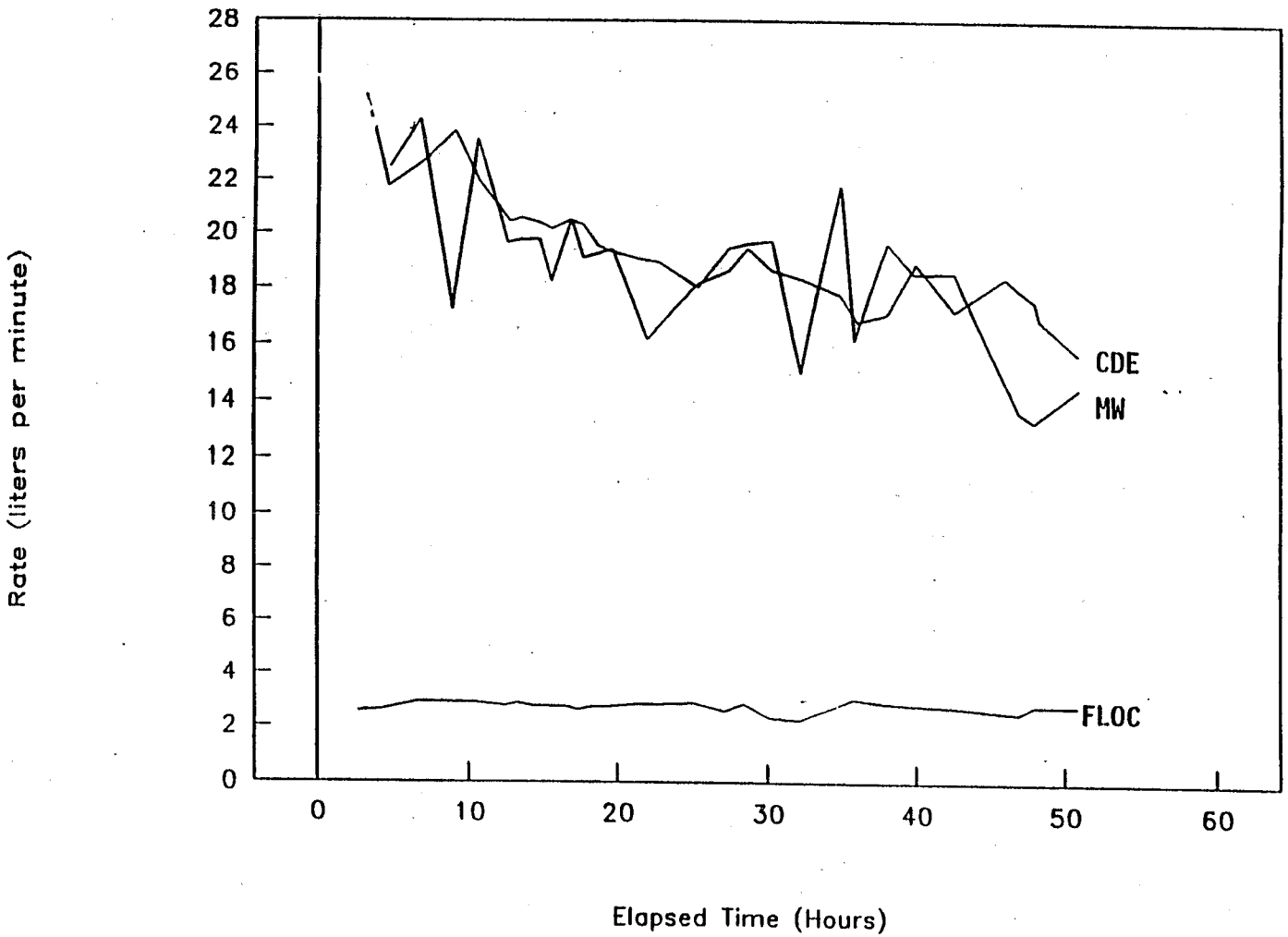



Figure 4-14. Aqueous Stream Rates - Low Penta SW Test

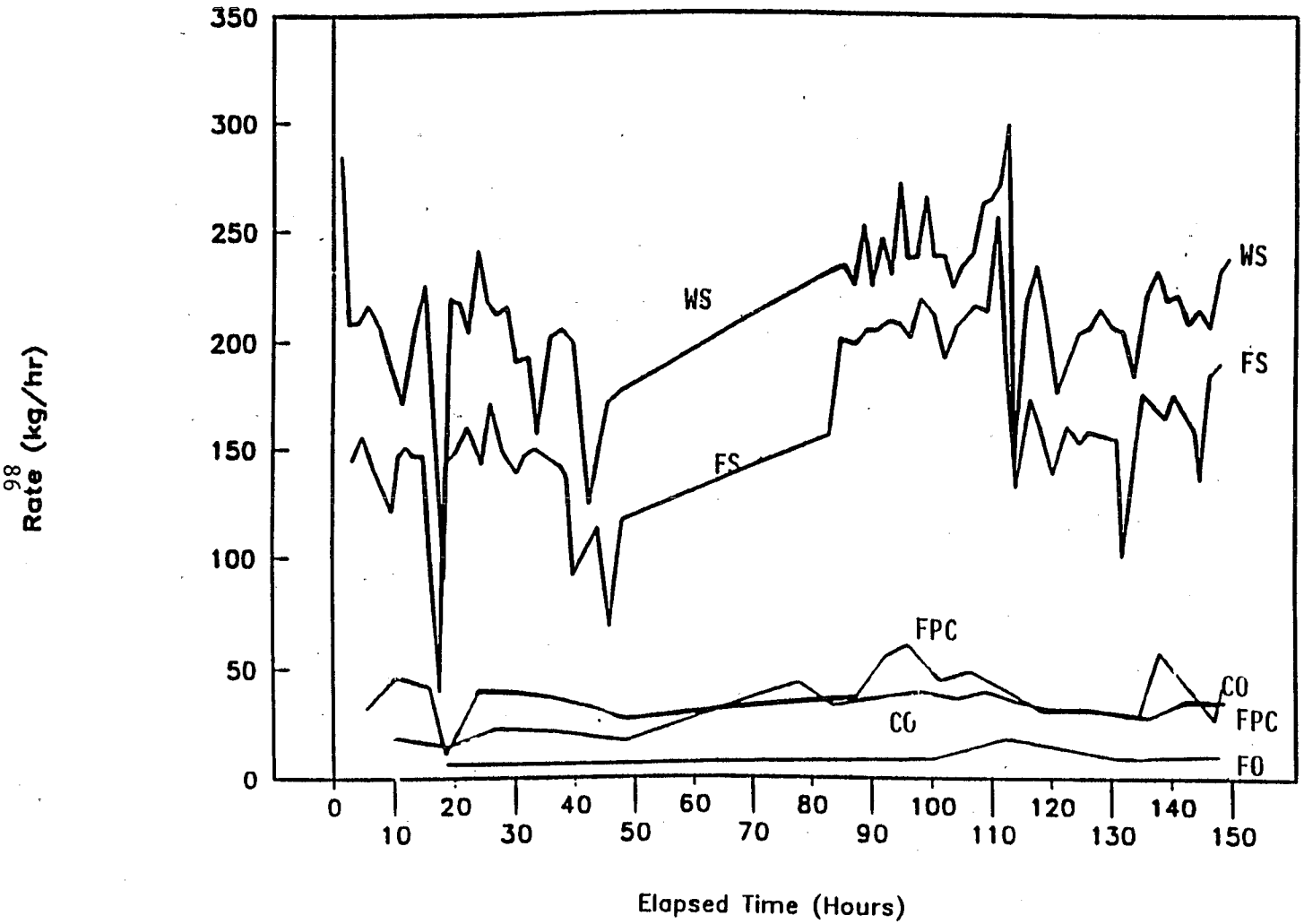



Figure 4-15. Solids Stream Flows - High Penta Soil Washer Test

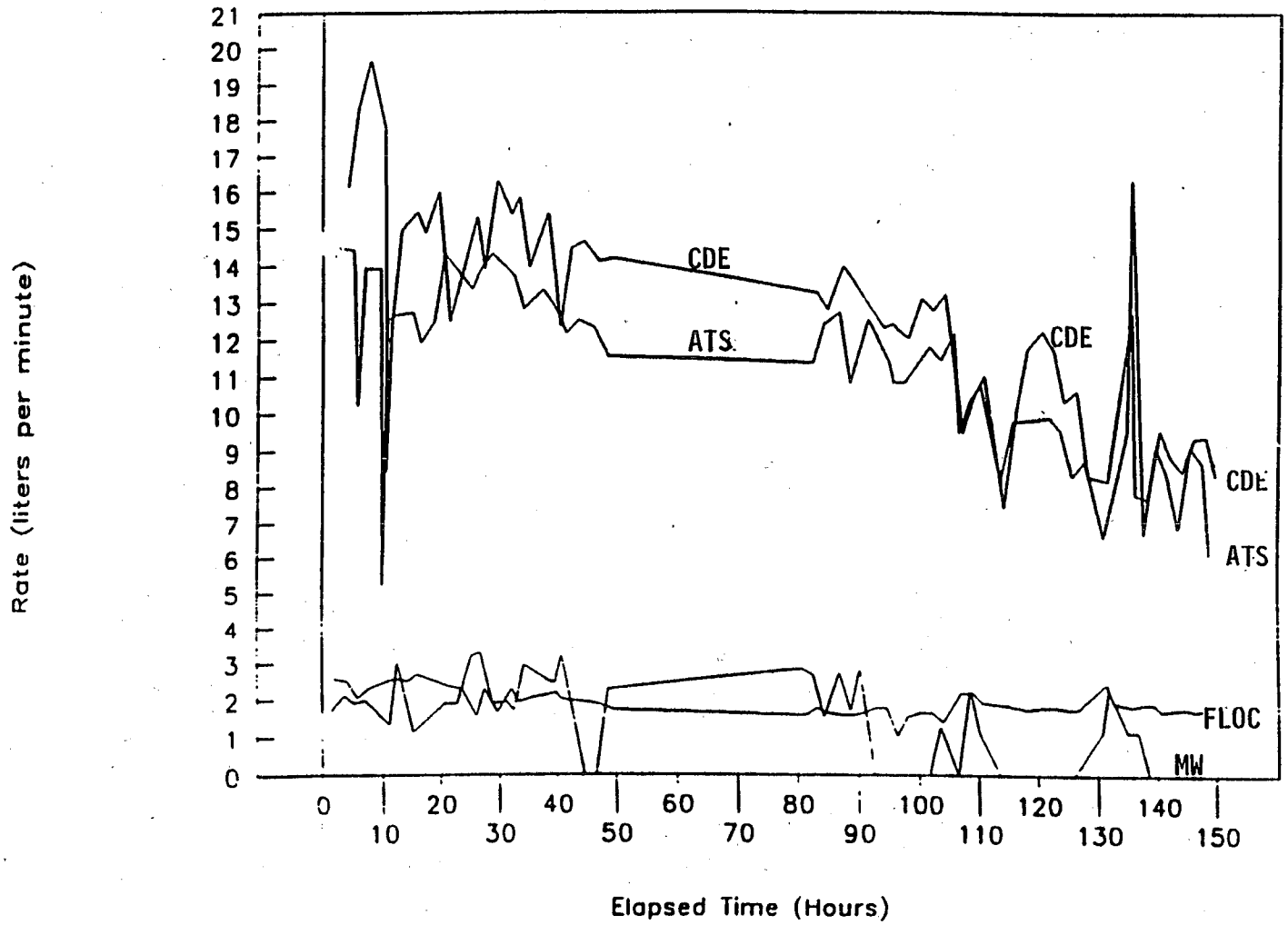



Figure 4-16. Aqueous Streams - High Penta SW Test

TABLE 4-30. COMPARISON OF AVERAGE AND WEIGHTED MASS FLOWS IN SOIL WASHER (Kg/hr)

| stream | Low Penta test weighted flow | avg. flow | std dev | High Penta test weighted flow | avg. flow | std dev |
|---|---|---|---|---|---|---|
| Feed Soil | 220 | 225.8 | 60.6 | 160 | 157.9 | 37.8 |
| Mun. Water | 1200 | 1156.0 | 163.8 | 35.2 | 75.5 | 69 |
| ATW | --- | --- | --- | 659.2 | 664.7 | 146.1 |
| Thickener | 180 | 161.2 | 10.5 | 120 | 113.6 | 20 |
| Washed Soil | 259.6 | 265.3 | 45.2 | 209.6 | 212.1 | 33.6 |
| Coarse Oversize | 30.8 | 32.7 | 5.4 | 28.8 | 31.8 | 9.8 |
| Fine Oversize | 13.0 | 12.8 | 0.7 | 9.6 | 9.8 | 3.8 |
| Fine Particle Cake | 48.4 | 50.7 | 15.2 | 35.2 | 36 | 10 |
| Comb. Dewater. Eff. | 1100 | 1120.8 | 118.8 | 720 | 743.8 | 176.9 |

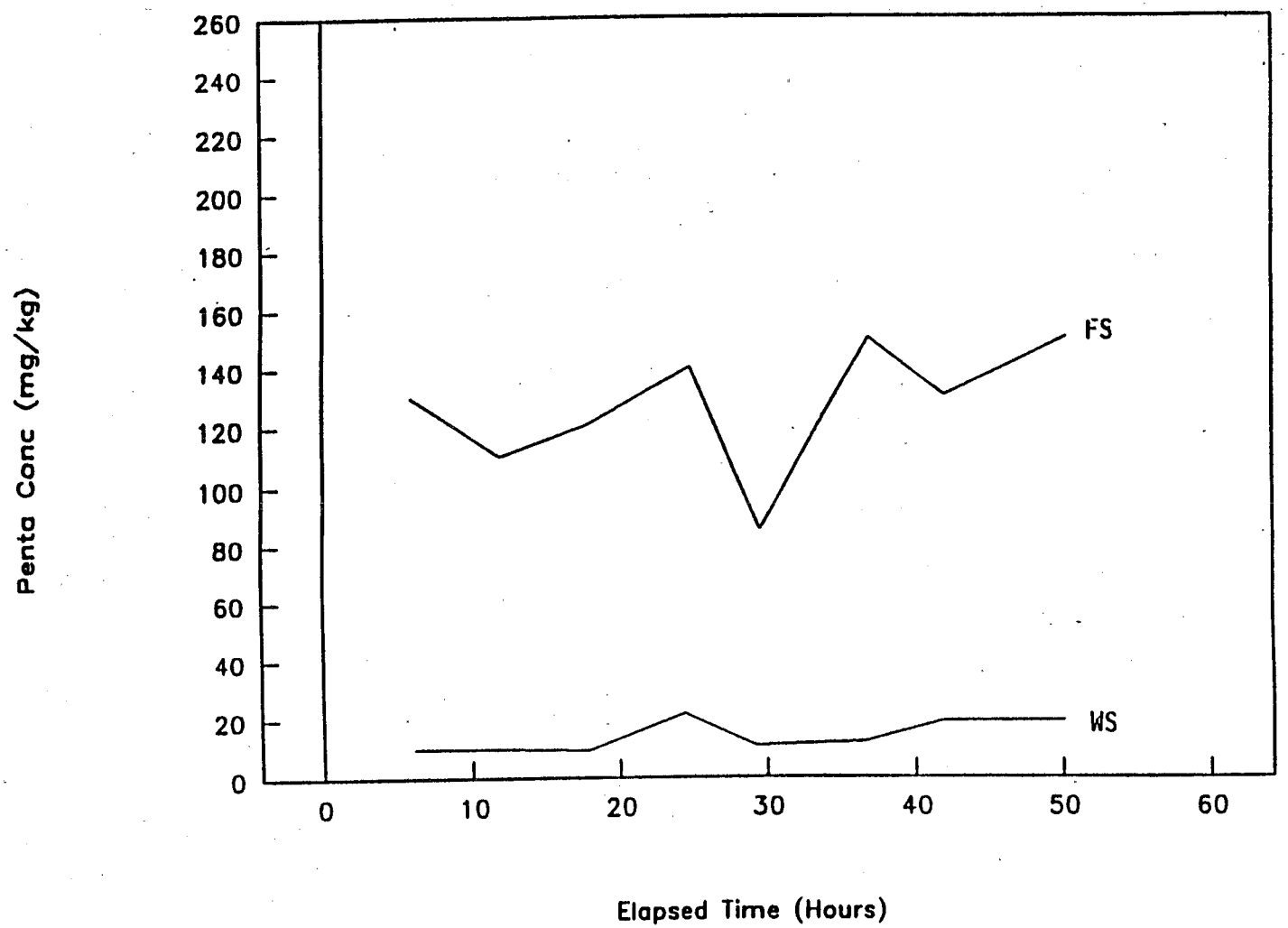



Figure 4-17. Penta Concentration - Washed and Feed Soil
Low Penta Soil Washer Test

(2) penta concentration in the Washed Soil appeared to remain stable between 10 and 20 mg/kg, averaging 14 ± 4.7 mg/kg (before data was weighted) while concentrations in the Feed Soil averaging 126.7 ± 20.4 mg/kg (before weighting) and ranged from 80 to 160 mg/kg.

During the High Penta SW test, the Soil Washer operated under three distinct Feed Soil flow rates: ~150 kg/hr, ~200 kg/hr, and fluctuations between 150 to 200 kg/hr. Analysis of variance between the three Feed Soil flow rates and Washed Soil penta concentration data indicates (Figure 4-18) that:

(1) penta concentration in the Washed Soil was not significantly different during the three Feed Soil flow rates; and

(2) penta concentration in the Washed Soil, with an average of 85.3 ± 30.8 mg/kg (before weighting), appeared to remain stable between 50 and 100 mg/kg while the concentration in the Feed Soil ranged between 300 and 1100 mg/kg (non-weighted average: 657.8 ± 228.5 mg/kg).

It may be noted that these observations could be interpreted as indicating that all penta that could be removed by the soil washing was being removed and increased time in the soil washer during low feed rate periods does not improve removal further.

A similar analysis of the PAH data from the Low Penta Soil Washer test suggests that:

(1) PAH concentrations in the Washed Soil also were not affected by decreases in Feed Soil flow rate during the Low Penta SW Test; and

(2) The total PAH concentration in the Washed Soil also appeared to stabilize, at an average of about 42 mg/kg, and the carcinogenic PAH concentration in the Washed Soil appeared to stabilize between 2 and 5 mg/kg (non-weighted average: 3.9 mg/kg) while Feed Soil concentration ranged between 30 and 60 mg/kg.

Analysis of the High Penta SW test data indicates that:

(1) Carcinogenic PAH concentration in the Washed Soil was not significantly different during the three Feed Soil flow rates; and

(2) Combined PAH concentration in the Washed Soil stabilized at an average of 48.3 mg/kg (non-weighted). Feed Soil concentration averaged 404.1 mg/kg.

Similar results were observed for TOC and TRPH. In the Low Penta SW test, TOC concentration in the Washed Soil stabilized between 1,400 and 2,300 mg/kg (average: 1,900 mg/kg) with Feed Soil concentration ranging between 4,000 and 21,000 mg/kg (average: 12,000 mg/kg). TRPH concentration in the Washed Soil stabilized between 100 and 300 mg/kg (average: 210 mg/kg) with Feed Soil concentration ranging between 2,000 and 10,000 mg/kg (average: 3,800 mg/kg).

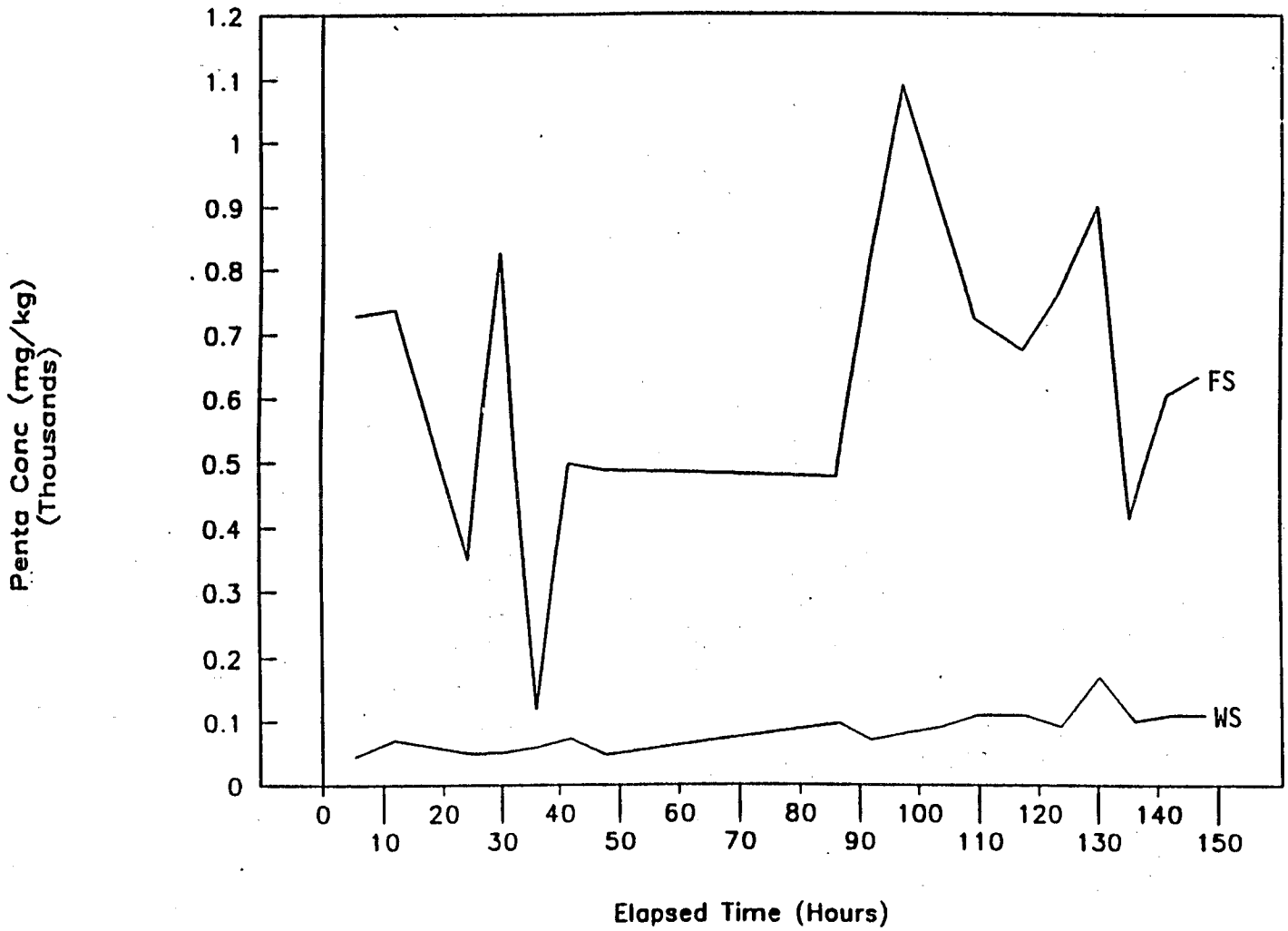



Figure 4-18. Penta Concentration - Washed and Feed Soil
High Penta Soil Washer Test

In the High Penta SW test, TOC in the Washed Soil stabilized between 1,000 and 5,000 mg/kg with concentrations in the Feed Soil ranging between 3,200 and 48,000 mg/kg. TRPH concentrations in the Washed Soil stabilized between 300 and 700 mg/kg with Feed Soil concentrations between 5,400 and 11,000 mg/kg.

### 4.4.3 BioTrol Aqueous Treatment System Performance

#### 4.4.3.1 Critical Analyses

Pentachlorophenol (Penta) -- During the BATS test with the process water from the Low Penta Soil Washer test, the weighted average influent concentration of penta was 15 ppm and the weighted average effluent concentration was 1.4 ppm. The calculated % removal is then 91%. These weighted values for the input or output were calculated by (1) multiplying each concentration by the volume of water during that sampling period to give a penta mass; (2) totalling all penta masses over the course of the test, and (3) dividing the total mass of penta for all input or output samples by the total volume of water treated (after excluded certain samples, as noted in the tables) to give a single, weighted average concentration in the influent or the output from the BATS.

During the second test, using process water from the High Penta SW test, the weighted average influent concentration of penta was 44 ppm and the weighted average effluent concentration was 3 ppm, corresponding to a 94% penta removal.

The data and mass balance calculations are presented in Tables 4-31 and 4-32 for the Low Penta and the High Penta tests, respectively.

The data indicate that "steady state" operation had not been achieved when sampling was initiated, and, in the case of the test with the High Penta process water, it required approximately 100 hours to stabilize. Nevertheless, it is evident that the BioTrol Aqueous Treatment System is effective at removing pentachlorophenol from the SW process water (Figures 4-19 and 4-20) once full acclimation and stabilization has been achieved.

Polynuclear Aromatic Hydrocarbons (PAHs) -- Concentrations of the various PAHs were lower than anticipated in both the BATS influent and effluent. During the BATS test with the Low Penta process water, only one PAH, anthracene, was detected with any frequency along with sporadic detections of acenaphthene, fluorene, phenanthrene, fluoranthene and pyrene. Almost all of the values reported were given a "J" qualifier which means the value is estimated because the compound was detected at a value greater than the method detection limit but below the quantitation limit. Analyses of effluent samples during this test yielded all non-detects. Method detection limits ranged from 2-15 ppb and were dependent upon the specific PAH compound. The data for anthracene are presented in Table 4-33. Calculations of removal were performed using the detection limit when non-detects occurred in the effluent and this yielded a minimum removal for anthracene of 69%.

Even though penta concentration was higher during the second BATS test, there were only sporadic detections of acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, and pyrene in the influent and effluent samples and they all were estimated values. There were insufficient detected

TABLE 4-31. BATS - LOW PENTA TEST
PERFORMANCE AND MATERIAL INVENTORY - PENTACHLOROPHENOL

| SAIC # | Penta Conc. (ug/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Penta Mass/Period (g) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN011DL | 12000 | # | 6 | 3719 | 45 |
| ATSIN012DL | 11000 | # | 12 | 3739 | 41 |
| ATSIN013DL | 14000 | | 18 | 3431 | 48 |
| ATSIN014DL | 16000 | | 25 | 4894 | 78 |
| ATSIN021DL | 39000 | | 32 | 3722 | 150 |
| ATSIN022DL | 11000 | | 38 | 3423 | 38 |
| ATSIN023REDL | 11000 | c | 45 | 4509 | 50 |
| ATSIN024DL | 16000 | | 51 | 3980 | 64 |
| ATSIN031DL | 11000 | | 57 | 3900 | 43 |
| ATSIN032DL | 13000 | | 64 | 3731 | 49 |
| ATSIN033DL | 15000 | | 71 | 4696 | 70 |
| ATSIN034DL | 8800 | b | 77 | 3867 | 34 |
| ATSIN041DL | 11000 | | 83 | 3774 | 42 |
| ATSIN042DL | 19000 | b | 89 | 4001 | 76 |
| AVG | 15400 | | | | |
| STD DEV | 7635 | | | | |
| WEIGHTED AVG: | 15000 | | TOTAL INFLUENT: | 55390 | 740 |
| Effluent Data | | | | | |
| ATSEFF011DL | 8600 | # | 6 | 3572 | 31 |
| ATSEFF012DL | 3900 | # | 12 | 3803 | 15 |
| ATSEFF013DL | 2400 | | 18 | 3344 | 8.0 |
| ATSEFF014DL | 2400 | | 25 | 3441 | 8.3 |
| ATSEFF021DL | 2600 | | 32 | 3626 | 9.4 |
| ATSEFF022DL | 1900 | | 38 | 3341 | 6.3 |
| ATSEFF023 | 1100 | | 45 | 4071 | 4.5 |
| ATSEFF024 | 1300 | | 51 | 4016 | 5.2 |
| ATSEFF031 | 1100 | b | 57 | 3782 | 4.2 |
| ATSEFF032 | 820 | | 64 | 3810 | 3.1 |
| ATSEFF033 | 1100 | | 71 | 4536 | 5.0 |
| ATSEFF034 | 850 | | 77 | 3804 | 3.2 |
| ATSEFF041 | 910 | | 83 | 3806 | 3.5 |
| ATSEFF042 | 910 | | 89 | 3837 | 3.5 |
| AVG | 1449 | | | | |
| STD DEV | 649 | | | | |
| WEIGHTED AVG: | 1300 | | TOTAL EFFLUENT: | 52790 | 60 |
| | | | PENTA MASS REDUCTION (g): | | 680 |
| | | | % MASS REMOVAL OF PENTA: | | 91 |

FILE NAME: ATSLPCPF

TABLE 4-31. (CONTINUED)

(1) - Data qualifiers used in subsequent data tables:

A = Analysis of an archive sample
B = Analyte found in associated method blank
C = Corrected analyte concentration
D = Diluted sample
E = Beyond calibration range
I = Interpolated or extrapolated analyte concentration
J = Below calibration range
L = Estimated detection limit
M = Mean analyte concentration
R = Replaced analyte concentration value
U = Undetected at specified concentration
W = Weighted average to replace missing data
X = Manually entered data
* = Statistically determined analyte concentration
+ = Concentration switched due to mislabelling of sample bottles
# = Biomass acclimation data not used in calculations

a = 1 to 28 days late to extract
b = 29 to 56 days late to extract
c = 57 to 84 days late to extract
d = 85 and over days late to extract
e = 1 to 28 days late to analyze
f = 29 to 56 days late to analyze
g = 57 to 84 days late to analyze
h = 85 and over days late to analyze

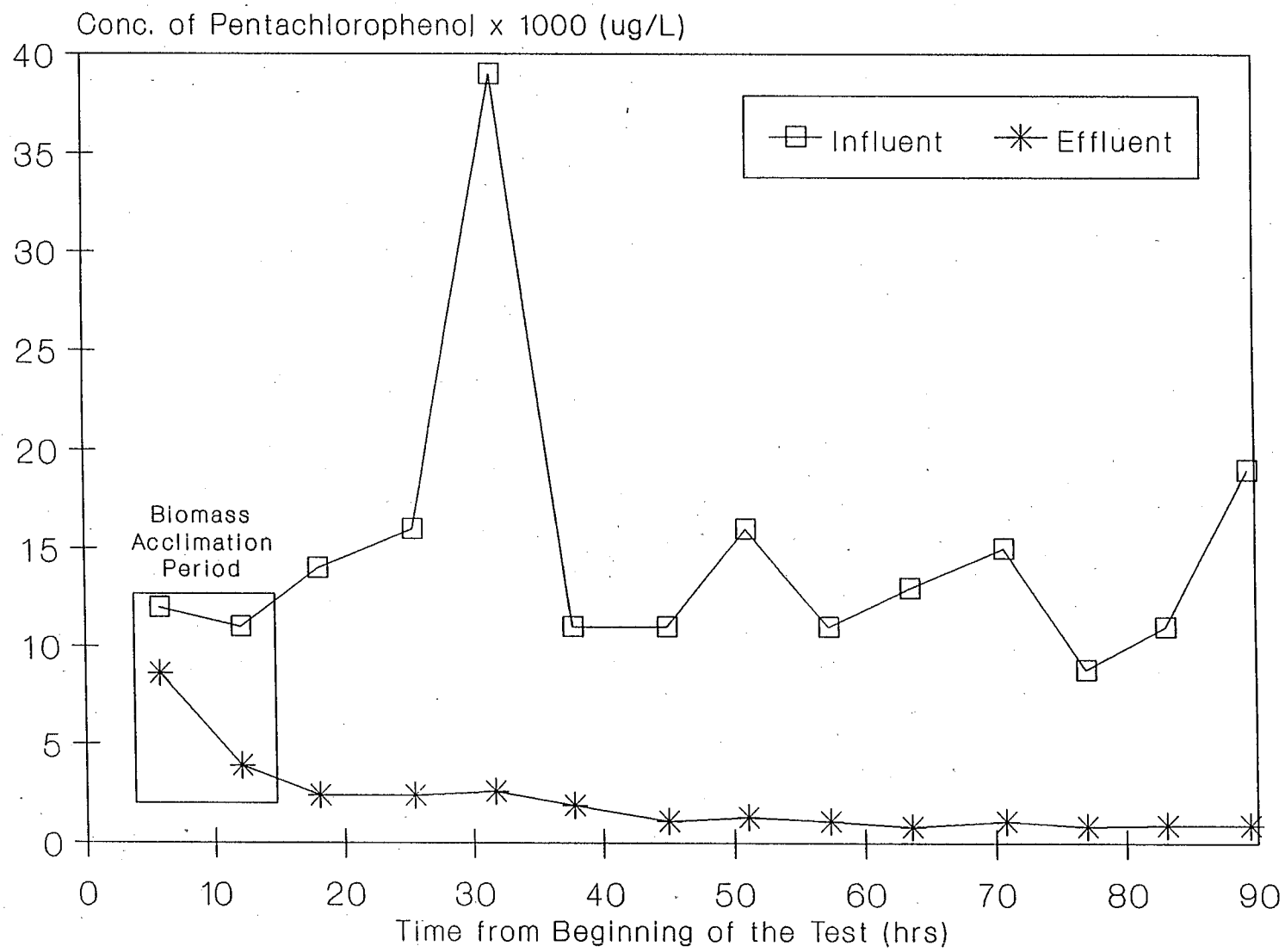
TABLE 4-32. BATS - HIGH PENTA TEST
PERFORMANCE AND MATERIAL INVENTORY - PENTACHLOROPHENOL

| SAIC # | Penta Conc. (ug/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Penta Mass/Period (g) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN043DL | 48000 | # | 96 | 4461 | 210 |
| ATSIN044DL | 83000 | # | 102 | 3930 | 330 |
| ATSIN051DL | 49000 | h | 108 | 3757 | 180 |
| ATSIN052DL | 80000 | | 115 | 4281 | 340 |
| ATSIN053DL | 39000 | M,h | 121 | 4670 | 180 |
| ATSIN054DL | 38000 | | 128 | 4156 | 160 |
| ATSIN061 | 44000 | W | 135 | 4938 | 220 |
| ATSIN062DL | 38000 | g | 140 | 3174 | 120 |
| ATSIN063 | 50000 | +,b,f | 146 | 4533 | 230 |
| ATSIN064 | 44000 | W | 153 | 3910 | 170 |
| ATSIN071 | 31000 | +,f | 159 | 3416 | 106 |
| ATSIN072DL | 38000 | g | 165 | 3117 | 120 |
| ATSIN073DL | 47000 | X | 172 | 3404 | 160 |
| ATSIN074DL | 32000 | h | 179 | 3168 | 100 |
| ATSIN081DL | 37000 | M,b,h | 185 | 4258 | 160 |
| ATSIN082DL | 43000 | M,b,e | 191 | 4717 | 200 |
| ATSIN083DL | 54000 | b,e | 198 | 4687 | 250 |
| ATSIN084DL | 42000 | b,e | 204 | 4817 | 200 |
| ATSIN091DL | 50000 | b | 210 | 4624 | 230 |
| ATSIN092 | 44000 | W | 217 | 4815 | 210 |
| ATSIN093DL | 38000 | b,f | 223 | 4552 | 170 |
| ATSIN094DL | 39000 | b,e | 229 | 3513 | 140 |
| ATSIN101DL | 28000 | b,g | 237 | 1263 | 35 |
| AVG | 43095 | | | | |
| STD DEV | 10469 | | | | |
| WEIGHTED AVG: | 44000 | | TOTAL INFLUENT: | 92160 | 3700 |
| Effluent Data | | | | | |
| ATSEFF043DL | 9700 | # | 96 | 4315 | 42 |
| ATSEFF044DL | 8300 | # | 102 | 3949 | 33 |
| ATSEFF051DL | 3100 | h | 108 | 3786 | 12 |
| ATSEFF052DL | 3200 | h | 115 | 4204 | 13 |
| ATSEFF053DL | 3000 | M,h | 121 | 4493 | 13 |
| ATSEFF054DL | 3200 | | 128 | 4014 | 13 |
| ATSEFF061DL | 2900 | g | 135 | 4812 | 14 |
| ATSEFF062 | 940 | h | 140 | 3146 | 3.0 |
| ATSEFF063 | 2600 | +,g | 146 | 4478 | 12 |
| ATSEFF064 | 2700 | W | 153 | 4131 | 11 |
| ATSEFF071 | 900 | +,f | 159 | 3395 | 3.1 |
| ATSEFF072 | 790 | | 165 | 3161 | 2.5 |
| ATSEFF073 | 560 | f | 172 | 2773 | 1.6 |
| ATSEFF074 | 1400 | h | 179 | 3488 | 4.9 |
| ATSEFF081DL | 2300 | M,h | 185 | 4090 | 9.4 |
| ATSEFF082 | 3800 | M,b,e | 191 | 4560 | 17 |
| ATSEFF083DL | 7500 | b,e | 198 | 4655 | 35 |
| ATSEFF084 | 2700 | W | 204 | 4849 | 13 |
| ATSEFF091DL | 2100 | b | 210 | 4486 | 9.4 |
| ATSEFF092DL | 2900 | b,g | 217 | 5092 | 15 |
| ATSEFF093DL | 2000 | b,f | 223 | 4251 | 8.5 |
| ATSEFF094DL | 2300 | b,e | 229 | 3613 | 8.3 |
| ATSEFF101 | 2700 | W | 237 | 1158 | 3.1 |
| AVG | 2552 | | | | |
| STD DEV | 1415 | | | | |
| WEIGHTED AVG: | 3000 | | TOTAL EFFLUENT: | 90900 | 220 |
| | | | PENTA MASS REDUCTION (g): | | 3480 |
| | | | % MASS REMOVAL OF PENTA: | | 94 |

FILE NAME: ATSHPCPF

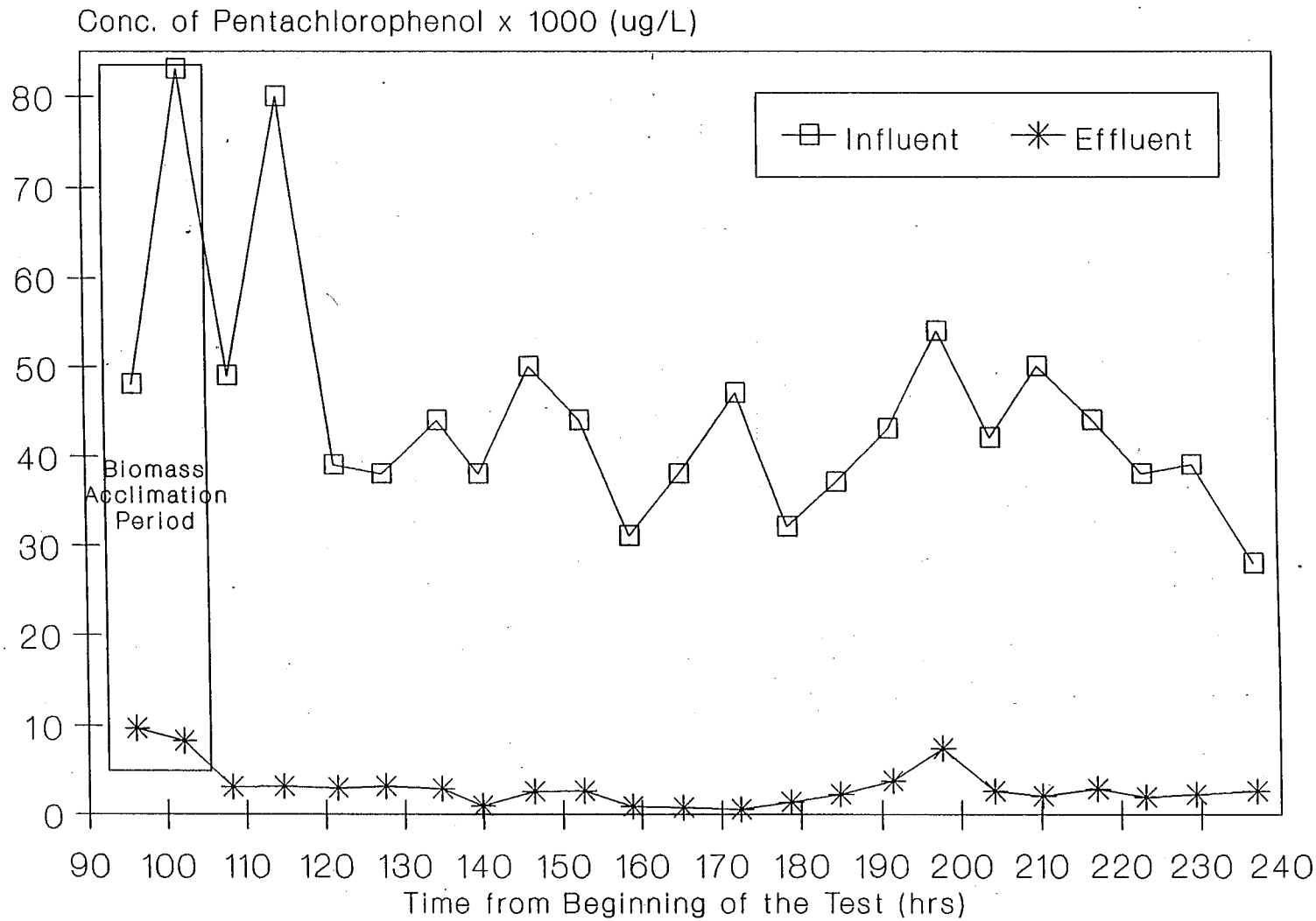
(1) A complete explanation of data qualifiers is provided in Table 4-27

## Figure 4-19. BATS-Penta Concentration in Low Penta Test




filename: PCPLCONC

Figure 4-20. BATS-Penta
Concentration in High Penta Test




filename: PCPHCONC

TABLE 4-33. BATS - LOW PENTA TEST
PERFORMANCE AND MATERIAL INVENTORY - ANTHRACENE

| SAIC # | Anthracene Conc. (ug/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Anthracene Mass/Period (g) |
|---|---|---|---|---|---|
| Influent data | | | | | |
| ATSIN011 | 69 | | 6 | 3719 | 0.26 |
| ATSIN012 | 41 | J | 12 | 3739 | 0.15 |
| ATSIN013 | 45 | J | 18 | 3431 | 0.15 |
| ATSIN014 | 35 | J | 25 | 4894 | 0.17 |
| ATSIN021 | 32 | J | 32 | 3722 | 0.12 |
| ATSIN022 | 23 | J,X | 38 | 3423 | 0.08 |
| ATSIN023 | 43 | | 45 | 4509 | 0.19 |
| ATSIN024 | 38 | J | 51 | 3980 | 0.15 |
| ATSIN031 | 34 | J | 57 | 3900 | 0.13 |
| ATSIN032 | 32 | J | 64 | 3731 | 0.12 |
| ATSIN033 | 22 | J | 71 | 4696 | 0.10 |
| ATSIN034 | 7.4 | *,b | 77 | 3867 | 0.03 |
| ATSIN041 | 7.4 | * | 83 | 3774 | 0.03 |
| ATSIN042 | 7.4 | *,b | 89 | 4001 | 0.03 |
| AVG | 31 | | | | |
| STD DEV | 16 | | | | |
| WEIGHTED AVG: | 31 | | TOTAL INFLUENT: | 55390 | 1.7 |
| Effluent data | | | | | |
| ATSEFF011 | 10 | L | 6 | 3572 | 0.04 |
| ATSEFF012 | 10 | L | 12 | 3803 | 0.04 |
| ATSEFF013 | 10 | L | 18 | 3344 | 0.03 |
| ATSEFF014 | 10 | L | 25 | 3441 | 0.03 |
| ATSEFF021 | 10 | L | 32 | 3626 | 0.04 |
| ATSEFF022 | 4 | L | 38 | 3341 | 0.01 |
| ATSEFF023 | 10 | L | 45 | 4071 | 0.04 |
| ATSEFF024 | 10 | L | 51 | 4016 | 0.04 |
| ATSEFF031 | 10 | L,b | 57 | 3782 | 0.04 |
| ATSEFF032 | 10 | L | 64 | 3810 | 0.04 |
| ATSEFF033 | 10 | L | 71 | 4536 | 0.05 |
| ATSEFF034 | 10 | L | 77 | 3804 | 0.04 |
| ATSEFF041 | 10 | L | 83 | 3806 | 0.04 |
| ATSEFF042 | 10 | L,h | 89 | 3837 | 0.04 |
| AVG | 9.6 | | | | |
| STD DEV | 1.5 | | | | |
| WEIGHTED AVG: | 9.6 | | TOTAL EFFLUENT: | 52790 | 0.51 |
| | | | MINIMUM ANTHRACENE MASS REDUCTION (g): | | 1.2 |
| | | | % MASS REMOVAL OF ANTHRACENE: | | 69-100 |

FILE NAME: ATSLANTF

(1) A complete explanation of data qualifiers is provided in Table 4-27

values to calculate percent removal for any PAHs in this test. Method detection limits ranged from 1-400 ppb.

The lack of actual analytical results above detection for both influent and effluent makes it impossible to assess the removal of PAHs across the system. The fact that all of the effluent samples analyzed from the first test (Low Penta) were reported as non-detects while some PAHs (e.g., anthracene) were measured in the influent suggests that some removal of these compounds was achieved; however, this removal can not be quantified.

Copper, Chromium, and Arsenic (CCA) -- Samples were analyzed for CCA to determine the fate of the metals in the BATS. The CCA data and material inventory for the tests with the process water from the Low Penta and High Penta SW tests are presented in Tables 4-34 and 4-35. There may be an upward trend in the concentration of arsenic and chromium in both the influent and the effluent samples of the BATS, probably reflecting a build-up of solubilized metals in the aqueous sample stream as it was recycled through the soil washer system.

While the system (SW or BATS) as tested is not designed to remove metals, the results indicate a 48% removal of copper mass and lower removals of chromium and arsenic. These removals, when none is expected, may suggest that there was some accumulation of metals inside the reactor. In a commercial scale system operated with full recycle of all process water for several months, metals could possibly build up to concentrations toxic to the microorganisms. Some discharge of water or treatment of metals in the system might then be required before continued recycle of process water.

#### 4.4.3.2 Other Analyses

Chloride Ion/Total Organic Halides -- Laboratory studies (Saber and Crawford, 1985; Crawford and Mohn, 1985) indicate that nearly complete mineralization occurs during biodegradation of penta with the Flavobacterium inoculated into the BATS. The penta is not simply converted to other organic compounds. Although none of the potential metabolites of biodegradation of penta were sought during the demonstration study (e.g., polychloroquinones, polychloro-dicarboxylic acids), samples were analyzed for chloride ion and total organic halides to ascertain whether the pentachlorophenol was being completely mineralized or only partially degraded.

The data for chloride and total organic halides (TOX) are presented in Table 4-36 along with the corresponding pentachlorophenol data and the calculated values for the theoretical chloride or TOX changes. For the first four samples, Cl ion concentrations increased from influent to effluent as expected, but for the last two samples Cl ion concentrations decreased while pentachlorophenol was significantly decreasing from influent to effluent.

Using the change in penta concentrations for each pair of influent and effluent samples, the increase in Cl ion concentration expected in the effluent samples was calculated on the basis of complete mineralization. Every mole of penta (266.5 gm) should produce 5 moles (177.5 gm) of chloride; this is equivalent to 0.67 mg/L of chloride produced for every mg/L of penta degraded. A correction was added to account for the chloride concentration in the influent.

TABLE 4-34. BATS - LOW PENTA TEST — MATERIAL INVENTORY - ARSENIC, CHROMIUM AND COPPER

| SAIC # | Arsenic (ug/L) | Q (1) | Chromium (ug/L) | Q (1) | Copper (ug/L) | Q (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Arsenic Mass/Period (mg) | Chromium Mass/Period (mg) | Copper Mass/Period (mg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent data | | | | | | | | | | | |
| ATSIN011 | 17.6 | | 6.80 | * | 35.1 | | 6 | 3719 | 65.5 | 25.3 | 131 |
| ATSIN012 | 17.6 | | 6.80 | * | 33.3 | | 12 | 3739 | 65.8 | 25.4 | 125 |
| ATSIN013 | 17.0 | | 13.0 | | 34.6 | | 18 | 3431 | 58.3 | 44.6 | 119 |
| ATSIN014 | 19.7 | | 6.80 | * | 26.2 | | 25 | 4894 | 96.4 | 33.3 | 128 |
| ATSIN021 | 13.1 | | 6.80 | * | 23.6 | | 32 | 3722 | 48.8 | 25.3 | 87.8 |
| ATSIN022 | 12.6 | | 6.80 | * | 24.9 | | 38 | 3423 | 43.1 | 23.3 | 85.2 |
| ATSIN023 | 14.0 | | 10.1 | | 23.7 | | 45 | 4509 | 63.1 | 45.5 | 107 |
| ATSIN024 | 13.0 | | 6.80 | * | 25.9 | | 51 | 3980 | 51.7 | 27.1 | 103 |
| ATSIN031 | 12.9 | | 6.80 | * | 23.1 | | 57 | 3900 | 50.3 | 26.5 | 90.1 |
| ATSIN032 | 12.1 | | 6.80 | * | 22.9 | | 64 | 3731 | 45.1 | 25.4 | 85.4 |
| ATSIN033 | 18.1 | | 19.1 | | 19.8 | | 71 | 4696 | 85.0 | 89.7 | 93.0 |
| ATSIN034 | 9.9 | | 13.0 | | 27.6 | | 77 | 3867 | 38.3 | 50.3 | 107 |
| ATSIN041 | 18.7 | | 18.3 | | 17.4 | | 83 | 3774 | 70.6 | 69.1 | 65.7 |
| ATSIN042 | 24.5 | | 19.5 | | 19.0 | | 89 | 4001 | 98.0 | 78.0 | 76.0 |
| AVG | 15.8 | | 10.5 | | 25.5 | | | | | | |
| STD DEV | 3.8 | | 4.9 | | 5.4 | | | | | | |
| WEIGHTED AVG: | 15.9 | | 10.6 | | 25.3 | | TOTAL INFLUENT: | 55390 | 880 | 589 | 1400 |
| Effluent data | | | | | | | | | | | |
| ATSEFF011 | 15.8 | | 5.92 | * | 8.61 | * | 6 | 3572 | 56.4 | 21.1 | 30.8 |
| ATSEFF012 | 17.2 | | 5.92 | * | 15.1 | | 12 | 3803 | 65.4 | 22.5 | 57.4 |
| ATSEFF013 | 18.0 | | 5.92 | * | 16.7 | | 18 | 3344 | 60.2 | 19.8 | 55.9 |
| ATSEFF014 | 21.0 | | 5.92 | * | 18.8 | | 25 | 3441 | 72.3 | 20.4 | 64.7 |
| ATSEFF021 | 14.2 | | 5.92 | * | 12.3 | | 31 | 3626 | 51.5 | 21.5 | 44.6 |
| ATSEFF022 | 12.6 | | 5.92 | * | 13.4 | | 37 | 3341 | 42.1 | 19.8 | 44.8 |
| ATSEFF023 | 14.1 | | 5.92 | * | 14.5 | | 45 | 4071 | 57.4 | 24.1 | 59.0 |
| ATSEFF024 | 13.8 | | 5.92 | * | 17.9 | | 51 | 4016 | 55.4 | 23.8 | 71.9 |
| ATSEFF031 | 12.7 | | 5.92 | * | 13.5 | | 57 | 3782 | 48.0 | 22.4 | 51.1 |
| ATSEFF032 | 12.2 | | 5.92 | * | 13.1 | | 63 | 3810 | 46.5 | 22.6 | 49.9 |
| ATSEFF033 | 17.7 | | 16.3 | | 8.61 | * | 71 | 4536 | 80.3 | 73.9 | 39.1 |
| ATSEFF034 | 17.4 | | 5.92 | * | 13.8 | | 77 | 3804 | 66.2 | 22.5 | 52.5 |
| ATSEFF041 | 16.3 | | 13.9 | | 8.61 | * | 83 | 3806 | 62.0 | 52.9 | 32.8 |
| ATSEFF042 | 16.3 | | 12.6 | | 8.61 | * | 89 | 3837 | 62.5 | 48.3 | 33.0 |
| AVG | 15.7 | | 7.7 | | 13.1 | | | | | | |
| STD DEV | 2.4 | | 3.5 | | 3.3 | | | | | | |
| WEIGHTED AVG: | 15.7 | | 7.9 | | 13.0 | | TOTAL EFFLUENT: | 52790 | 826 | 416 | 687 |
| | | | | | | | MATERIAL LOSS (mg): | | 54 | 173 | 713 |
| | | | | | | | % MASS REMOVAL: | | 1.5 | 26 | 48 |

FILE NAME: ATSLCCAF

(1) A complete explanation of data qualifiers is provided in Table 4-27

TABLE 4-35. BATS - HIGH PENTA TEST -- MATERIAL INVENTORY - ARSENIC, CHROMIUM AND COPPER

| SAIC # | Arsenic (ug/L) | Q (1) | Chromium (ug/L) | Q (1) | Copper (ug/L) | Q (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Arsenic Mass/Period (mg) | Chromium Mass/Period (mg) | Copper Mass/Period (mg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent data | | | | | | | | | | | |
| ATSIN043 | 57.7 | | 13.2 | | 32.3 | | 96 | 4461 | 257 | 58.9 | 144 |
| ATSIN044 | 59.9 | | 18.5 | | 26.7 | | 102 | 3930 | 235 | 72.7 | 105 |
| ATSIN051 | 59.8 | | 10.5 | | 28.6 | | 108 | 3757 | 225 | 39.5 | 107 |
| ATSIN052 | 57.9 | | 10.4 | | 32.6 | | 115 | 4281 | 248 | 44.5 | 140 |
| ATSIN053 | 59.3 | | 12.1 | | 33.4 | | 121 | 4670 | 277 | 56.5 | 156 |
| ATSIN054 | 76.9 | | 27.7 | | 24.7 | | 128 | 4156 | 320 | 115 | 103 |
| ATSIN061 | 90.8 | | 17.0 | | 26.2 | | 135 | 4938 | 448 | 84.0 | 129 |
| ATSIN062 | 52.4 | | 8.72 | * | 32.5 | | 140 | 3174 | 166 | 27.7 | 103 |
| ATSIN063 | 56.3 | | 11.1 | | 27.1 | | 146 | 4533 | 255 | 50.3 | 123 |
| ATSIN064 | 67.1 | | 10.2 | | 22.3 | | 153 | 3910 | 262 | 39.9 | 87.2 |
| ATSIN071 | 59.7 | | 8.72 | * | 20.6 | | 159 | 3416 | 204 | 29.8 | 70.4 |
| ATSIN072 | 65.5 | | 23.0 | | 45.1 | | 165 | 3117 | 204 | 71.7 | 141 |
| ATSIN073 | 60.9 | | 19.6 | | 43.6 | | 172 | 3404 | 207 | 66.7 | 148 |
| ATSIN074 | 71.3 | | 16.6 | | 39.4 | | 179 | 3168 | 226 | 52.6 | 125 |
| ATSIN081 | 57.3 | | 18.5 | | 43.8 | | 185 | 4258 | 244 | 78.8 | 187 |
| ATSIN082 | 69.5 | | 18.8 | | 47.0 | | 191 | 4717 | 328 | 88.7 | 222 |
| ATSIN083 | 79.9 | | 17.6 | | 57.5 | | 198 | 4687 | 374 | 82.5 | 269 |
| ATSIN084 | 40.3 | | 16.1 | | 47.6 | | 204 | 4817 | 194 | 77.5 | 229 |
| ATSIN091 | 75.1 | | 17.2 | | 55.3 | | 210 | 4624 | 347 | 79.5 | 256 |
| ATSIN092 | 65.7 | | 19.6 | | 57.4 | | 217 | 4815 | 316 | 94.4 | 276 |
| ATSIN093 | 76.1 | | 19.6 | | 61.2 | | 223 | 4552 | 346 | 89.2 | 279 |
| ATSIN094 | 87.0 | | 20.4 | | 68.8 | | 229 | 3513 | 306 | 71.7 | 242 |
| ATSIN101 | 73.2 | | 17.3 | | 65.0 | | 237 | 1263 | 92.5 | 21.9 | 82.1 |
| AVG | 66.1 | | 16.2 | | 40.8 | | | | | | |
| STD DEV | 11.4 | | 4.8 | | 14.3 | | | | | | |
| WEIGHTED AVG: | 66.0 | | 16.2 | | 40.4 | | TOTAL INFLUENT: | 92160 | 6080 | 1490 | 3720 |

TABLE 4-35. BATS - HIGH PENTA TEST -- MATERIAL INVENTORY - ARSENIC, CHROMIUM AND COPPER (CONTINUED)

| SAIC # | Arsenic (ug/L) | Q (1) | Chromium (ug/L) | Q (1) | Copper (ug/L) | Q (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Arsenic Mass/Period (mg) | Chromium Mass/Period (mg) | Copper Mass/Period (mg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Effluent data | | | | | | | | | | | |
| ATSEFF043 | 41.6 | | 8.79 | * | 14.8 | | 96 | 4315 | 179 | 37.9 | 63.9 |
| ATSEFF044 | 46.4 | | 12.9 | | 13.3 | | 102 | 3949 | 183 | 50.9 | 52.5 |
| ATSEFF051 | 48.9 | | 8.79 | * | 17.7 | | 108 | 3786 | 185 | 33.3 | 67.0 |
| ATSEFF052 | 50.8 | | 8.79 | * | 17.7 | | 115 | 4204 | 214 | 37.0 | 74.4 |
| ATSEFF053 | 55.4 | | 8.79 | * | 22.5 | | 121 | 4493 | 249 | 39.5 | 101 |
| ATSEFF054 | 74.4 | | 14.8 | | 11.4 | | 128 | 4014 | 299 | 59.4 | 45.8 |
| ATSEFF061 | 56.7 | | 17.3 | | 11.6 | | 135 | 4812 | 273 | 83.2 | 55.8 |
| ATSEFF062 | 46.0 | | 8.79 | * | 21.1 | | 140 | 3146 | 145 | 27.7 | 66.4 |
| ATSEFF063 | 59.7 | | 14.9 | | 32.8 | | 146 | 4478 | 267 | 66.7 | 147 |
| ATSEFF064 | 67.2 | | 18.3 | | 39.5 | | 153 | 4131 | 278 | 75.6 | 163 |
| ATSEFF071 | 62.0 | | 18.7 | | 41.7 | | 159 | 3395 | 210 | 63.5 | 142 |
| ATSEFF072 | 49.6 | | 11.5 | | 25.5 | | 165 | 3161 | 157 | 36.3 | 80.6 |
| ATSEFF073 | 65.3 | | 11.0 | | 23.9 | | 172 | 2773 | 181 | 30.5 | 66.3 |
| ATSEFF074 | 69.8 | | 11.8 | | 20.9 | | 179 | 3488 | 243 | 41.2 | 72.9 |
| ATSEFF081 | 57.4 | | 13.2 | | 32.3 | | 185 | 4090 | 235 | 54.0 | 132 |
| ATSEFF082 | 45.6 | | 10.7 | | 26.6 | | 191 | 4560 | 208 | 48.8 | 121 |
| ATSEFF083 | 5.7 | | 11.3 | | 24.3 | | 198 | 4655 | 26.5 | 52.6 | 113 |
| ATSEFF084 | 68.0 | | 11.3 | | 33.8 | | 204 | 4849 | 330 | 54.8 | 164 |
| ATSEFF091 | 56.9 | | 11.7 | | 26.1 | | 210 | 4486 | 255 | 52.5 | 117 |
| ATSEFF092 | 55.9 | | 11.2 | | 20.8 | | 217 | 5092 | 285 | 57.0 | 106 |
| ATSEFF093 | 57.9 | | 10.9 | | 38.5 | | 223 | 4251 | 246 | 46.3 | 164 |
| ATSEFF094 | 61.0 | | 14.4 | | 46.7 | | 229 | 3613 | 220 | 52.0 | 169 |
| ATSEFF101 | 57.7 | | 12.8 | | 35.1 | | 237 | 1158 | 66.8 | 14.8 | 40.7 |
| AVG | 54.8 | | 12.3 | | 26.0 | | | | | | |
| STD DEV | 13.3 | | 2.9 | | 9.7 | | | | | | |
| WEIGHTED AVG: | 54.3 | | 12.3 | | 25.5 | | TOTAL EFFLUENT: | 90900 | 4940 | 1120 | 2320 |
| | | | | | | | MATERIAL LOSS (mg): | | 1140 | 370 | 1400 |
| | | | | | | | % MASS REMOVAL: | | 18 | 24 | 37 |

FILE NAME: ATSHCCAF

(1) A complete explanation of data qualifiers is provided in Table 4-27

TABLE 4-36. ATS PENTA MINERALIZATION ASSESSMENT

| Influent ATSIN | Penta (mg/L) | Cl (mg/L) | TOX (mg/L) | Effluent ATSEFF | Penta (mg/L) | Cl (mg/L) | TOX (mg/L) | Change in Cl | | Change in TOX | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | found | calc* | found | calc* |
| 042 | 19.0 | 33.9 | 7.7 | 042 | 0.9 | 43.4 | 8.8 | 9.5 | 12.1 | 1.1 | 12.1 |
| 044 | 83.0 | 54.3 | 17.0 | 044 | 8.3 | 83.7 | 13.0 | 29.4 | 49.8 | -4.0 | 49.8 |
| 052 | 80.0 | 50.0 | 19.0 | 052 | 3.2 | 82.8 | 11.0 | 32.8 | 51.2 | -8.0 | 51.2 |
| 054 | 38.0 | 55.0 | 15.0 | 054 | 3.2 | 87.5 | 7.8 | 32.5 | 23.2 | -7.2 | 23.2 |
| 062 | 38.0 | 116.0 | 11.0 | 062 | 0.9 | 100.0 | 15.0 | -16.0 | 24.7 | 4.0 | 24.7 |
| 064 | 44.0 | 106.0 | 2.4 | 064 | 2.7 | 58.4 | 9.0 | -47.6 | 27.5 | 6.6 | 27.5 |

FILENAME: ATSCLTOX

* Every mg/L of penta is equivalent to 0.667 mg/L of Cl- and TOX; every mg/L of penta removed should increase Cl- and decrease TOX by 0.667 mg/L

Actual and calculated chloride concentrations in the effluent are not in good agreement and the effluent chloride values vary widely. Thus, this data can not be used to confirm that the decrease in penta concentration was due to mineralization of the penta.

Examination of the data for total organic halides (also shown in Table 4-36) indicates that only three of the samples show a decrease in concentration of TOX between influent and effluent, the other three samples show an increase. Consequently, no conclusions can be drawn from this data as to whether the chloride leaving the system is purely inorganic.

Total Solids -- Analyses for total solids (suspended and dissolved) also were performed on the influent and effluent samples of the BioTrol Aqueous Treatment System during each study. Results for Total Solids along with material balances are presented in Tables 4-37 and 4-38. The material balance data show only an 8.6% loss of solids during the Low Penta test and a 4% gain in solids during the High Penta test. It is possible that there was a slight build-up of solids during the Low Penta test that was later released during the High Penta test. Alternatively, the slight differences are also well within the precision of the Total Residue (TR) test.

Total Recoverable Petroleum Hydrocarbons -- The TRPH analyses were intended as a measure of the oil (used as a carrier for penta during wood treating operations at MacGillis & Gibbs) in the soil and consequently expected in the process water leaving the Soil Washer and entering the BATS. Results for TRPHs are presented in Tables 4-39 and 4-40. The TRPH values were in the low ppm range in all of the aqueous process streams, indicating that there was not a significant oil content in the feed soils or that the oil did not transfer to the aqueous process stream during soil washing. Removals of TRPHs were only 18% and 42% in the Low Penta and High Penta studies, respectively. If significant amounts of oil had been present and there were reason to suspect that it were adversely affecting the BSWS, a means of oil removal such as an oil water separator would need to be added as a pretreatment step before the BATS.

Chemical Oxygen Demand (COD) -- Chemical Oxygen Demand was examined as a measure of the total potential oxidizable material in the samples. COD was included rather than biochemical oxygen demand (BOD) because of its simplicity and because it avoids BOD test problems concerning sample toxicity, refractory contaminants, and the need to develop an influent sample inoculation procedure. Since the BSWS includes biological treatment, measurements of COD decrease reflect overall reduction of organic contaminants including those being analyzed for as primary and secondary contaminants.

Measurements of COD confirmed that oxidation was occurring, albeit not to a very great extent. The data were very erratic (Tables 4-41 and 4-42) and the decrease in COD from influent to effluent is not very pronounced (14% and 47% in either test, respectively). One possible explanation is that the primary contaminants, penta and PAHs, only constitute a small fraction of the total organic contamination in the system.

TABLE 4-37. BATS -- LOW PENTA TEST MATERIAL INVENTORY - TOTAL SOLIDS

| SAIC # | Total Solids (mg/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Total Solids/Period (kg) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN011 | 539 | | 6 | 3719 | 2.00 |
| ATSIN012 | 545 | | 12 | 3739 | 2.04 |
| ATSIN013 | 527 | | 18 | 3431 | 1.81 |
| ATSIN014 | 535 | | 25 | 4894 | 2.62 |
| ATSIN021 | 501 | | 32 | 3722 | 1.86 |
| ATSIN022 | 502 | | 38 | 3423 | 1.72 |
| ATSIN023 | 491 | | 45 | 4509 | 2.21 |
| ATSIN024 | 680 | | 51 | 3980 | 2.7 |
| ATSIN031 | 614 | | 57 | 3900 | 2.39 |
| ATSIN032 | 683 | | 64 | 3731 | 2.55 |
| ATSIN033 | 472 | | 71 | 4696 | 2.22 |
| ATSIN034 | 500 | | 77 | 3867 | 2 |
| ATSIN041 | 547 | W | 83 | 3774 | 2.07 |
| ATSIN042 | 547 | W | 89 | 4001 | 2.19 |
| AVG | 549 | | | | |
| STD DEV | 63 | | | | |
| WEIGHTED AVG: | 547 | | TOTAL INFLUENT: | 55390 | 30.3 |
| Effluent Data | | | | | |
| ATSEFF011 | 462 | A | 6 | 3572 | 1.65 |
| ATSEFF012 | 524 | | 12 | 3803 | 1.99 |
| ATSEFF013 | 473 | | 18 | 3344 | 1.58 |
| ATSEFF014 | 515 | | 25 | 3441 | 1.77 |
| ATSEFF021 | 432 | | 32 | 3626 | 1.57 |
| ATSEFF022 | 463 | | 38 | 3341 | 1.55 |
| ATSEFF023 | 446 | | 45 | 4071 | 1.82 |
| ATSEFF024 | 622 | | 51 | 4016 | 2.50 |
| ATSEFF031 | 590 | | 57 | 3782 | 2.23 |
| ATSEFF032 | 658 | | 64 | 3810 | 2.51 |
| ATSEFF033 | 525 | W | 71 | 4536 | 2.38 |
| ATSEFF034 | 568 | | 77 | 3804 | 2.16 |
| ATSEFF041 | 525 | W | 83 | 3806 | 2.00 |
| ATSEFF042 | 525 | W | 89 | 3837 | 2.01 |
| AVG | 523 | | | | |
| STD DEV | 65 | | | | |
| WEIGHTED AVG: | 525 | | TOTAL EFFLUENT: | 52790 | 27.7 |
| | | | MATERIAL LOSS (kg): | | 2.6 |
| | | | % MATERIAL LOSS: | | 8.5 |

FILE NAME: ATSLTRF

(1) A complete explanation of data qualifiers is provided in Table 4-27

TABLE 4-38. BATS – HIGH PENTA TEST MATERIAL INVENTORY – TOTAL SOLIDS

| SAIC # | Total Solids (mg/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | Total Solids/Period (kg) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN043 | 507 | A | 96 | 4461 | 2.26 |
| ATSIN044 | 489 | W | 102 | 3930 | 1.92 |
| ATSIN051 | 273 | A | 108 | 3757 | 1.03 |
| ATSIN052 | 303 | A | 115 | 4281 | 1.30 |
| ATSIN053 | 522 | | 121 | 4670 | 2.44 |
| ATSIN054 | 337 | | 128 | 4156 | 1.40 |
| ATSIN061 | 489 | W | 135 | 4938 | 2.42 |
| ATSIN062 | 546 | A | 140 | 3174 | 1.73 |
| ATSIN063 | 503 | | 146 | 4533 | 2.28 |
| ATSIN064 | 359 | | 153 | 3910 | 1.40 |
| ATSIN071 | 451 | | 159 | 3416 | 1.54 |
| ATSIN072 | 563 | | 165 | 3117 | 1.75 |
| ATSIN073 | 536 | A | 172 | 3404 | 1.82 |
| ATSIN074 | 545 | A | 179 | 3168 | 1.73 |
| ATSIN081 | 497 | A | 185 | 4258 | 2.12 |
| ATSIN082 | 525 | W,M | 191 | 4717 | 2.48 |
| ATSIN083 | 489 | W | 198 | 4687 | 2.29 |
| ATSIN084 | 510 | A | 204 | 4817 | 2.46 |
| ATSIN091 | 715 | A | 210 | 4624 | 3.31 |
| ATSIN092 | 570 | | 217 | 4815 | 2.74 |
| ATSIN093 | 489 | W | 223 | 4552 | 2.23 |
| ATSIN094 | 530 | | 229 | 3513 | 1.86 |
| ATSIN101 | 593 | A | 237 | 1263 | 0.75 |
| AVG | 493 | | | | |
| STD DEV | 96 | | | | |
| WEIGHTED AVG: | 491 | | TOTAL INFLUENT: | 92160 | 45 |
| Effluent Data | | | | | |
| ATSEFF043 | 517 | W | 96 | 4315 | 2.23 |
| ATSEFF044 | 514 | | 102 | 3949 | 2.03 |
| ATSEFF051 | 356 | A | 108 | 3786 | 1.35 |
| ATSEFF052 | 546 | M | 115 | 4204 | 2.30 |
| ATSEFF053 | 408 | A | 121 | 4493 | 1.83 |
| ATSEFF054 | 875 | | 128 | 4014 | 3.51 |
| ATSEFF061 | 517 | W | 135 | 4812 | 2.49 |
| ATSEFF062 | 528 | A | 140 | 3146 | 1.66 |
| ATSEFF063 | 522 | A | 146 | 4478 | 2.34 |
| ATSEFF064 | 517 | | 153 | 4131 | 2.13 |
| ATSEFF071 | 517 | W | 159 | 3395 | 1.76 |
| ATSEFF072 | 566 | | 165 | 3161 | 1.79 |
| ATSEFF073 | 528 | | 172 | 2773 | 1.46 |
| ATSEFF074 | 542 | A | 179 | 3488 | 1.89 |
| ATSEFF081 | 363 | A | 185 | 4090 | 1.48 |
| ATSEFF082 | 536 | A | 191 | 4560 | 2.44 |
| ATSEFF083 | 486 | A | 198 | 4655 | 2.26 |
| ATSEFF084 | 331 | A | 204 | 4849 | 1.60 |
| ATSEFF091 | 517 | W | 210 | 4486 | 2.32 |
| ATSEFF092 | 517 | W | 217 | 5092 | 2.63 |
| ATSEFF093 | 590 | | 223 | 4251 | 2.51 |
| ATSEFF094 | 620 | | 229 | 3613 | 2.24 |
| ATSEFF101 | 647 | A | 237 | 1158 | 0.75 |
| AVG | 524 | | | | |
| STD DEV | 107 | | | | |
| WEIGHTED AVG: | 517 | | TOTAL EFFLUENT: | 90900 | 47 |
| | | | MATERIAL GAIN (kg): | | 1.8 |
| | | | % MATERIAL GAIN: | | 4 |

FILE NAME: ATSHTRF

(1) A complete explanation of data qualifiers is provided in Table 4-27

TABLE 4-39. BATS - LOW PENTA TEST - MATERIAL INVENTORY - TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (TRPH)

| SAIC # | TRPH (mg/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | TRPH/ Period (g) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN011 | 4.82 | J | 6 | 3719 | 17.9 |
| ATSIN012 | 6.98 | J | 12 | 3739 | 26.1 |
| ATSIN013 | 9.79 | J | 18 | 3431 | 33.6 |
| ATSIN014 | 8.38 | | 25 | 4894 | 41.0 |
| ATSIN021 | 2.96 | | 32 | 3722 | 11.0 |
| ATSIN022 | 5.00 | | 38 | 3423 | 17.1 |
| ATSIN023 | 4.57 | J | 45 | 4509 | 20.6 |
| ATSIN024 | 5.47 | J | 51 | 3980 | 21.8 |
| ATSIN031 | 6.80 | J | 57 | 3900 | 26.5 |
| ATSIN032 | 5.00 | J | 64 | 3731 | 18.7 |
| ATSIN033 | 4.23 | J | 71 | 4696 | 19.9 |
| ATSIN034 | 6.62 | J | 77 | 3867 | 25.6 |
| ATSIN041 | 5.05 | J | 83 | 3774 | 19.1 |
| ATSIN042 | 3.37 | J | 89 | 4001 | 13.5 |
| AVG | 5.65 | | | | |
| STD DEV | 1.82 | | | | |
| WEIGHTED AVG: | 5.64 | | TOTAL INFLUENT: | 55390 | 312 |
| Effluent Data | | | | | |
| ATSEFF011 | 4.01 | | 6 | 3572 | 14.3 |
| ATSEFF012 | 3.16 | J | 12 | 3803 | 12.0 |
| ATSEFF013 | 3.92 | J | 18 | 3344 | 13.1 |
| ATSEFF014 | 3.65 | | 26 | 3441 | 12.6 |
| ATSEFF021 | 5.30 | | 32 | 3626 | 19.2 |
| ATSEFF022 | 4.30 | | 38 | 3341 | 14.4 |
| ATSEFF023 | 9.45 | J | 45 | 4071 | 38.5 |
| ATSEFF024 | 5.01 | J | 51 | 4016 | 20.1 |
| ATSEFF031 | 11.00 | J | 57 | 3782 | 41.6 |
| ATSEFF032 | 4.95 | J | 64 | 3810 | 18.9 |
| ATSEFF033 | 3.47 | J | 71 | 4536 | 15.7 |
| ATSEFF034 | 4.69 | J | 77 | 3804 | 17.8 |
| ATSEFF041 | 2.67 | J | 83 | 3806 | 10.2 |
| ATSEFF042 | 1.85 | * | 89 | 3837 | 7.1 |
| AVG | 4.82 | | | | |
| STD DEV | 2.41 | | | | |
| WEIGHTED AVG: | 4.84 | | TOTAL EFFLUENT: | 52790 | 255 |
| | | | MATERIAL LOSS (g): | | 56.8 |
| | | | % MASS REMOVAL: | | 18 |

FILE NAME: ATSLTPHF

(1) A complete explanation of data qualifiers is provided in Table 4-27

TABLE 4–40. BATS – HIGH PENTA TEST — MATERIAL INVENTORY
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (TRPH)

| SAIC # | TRPH (mg/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | TRPH/ Period (g) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN043 | 6.48 | J | 96 | 4461 | 28.9 |
| ATSIN044 | 1.35 | * | 102 | 3930 | 5.32 |
| ATSIN051 | 2.39 | J | 108 | 3757 | 8.98 |
| ATSIN052 | 1.46 | * | 115 | 4281 | 6.23 |
| ATSIN053 | 2.53 | M,J | 121 | 4670 | 11.8 |
| ATSIN054 | 6.42 | J | 128 | 4156 | 26.7 |
| ATSIN061 | 3.11 | J | 135 | 4938 | 15.4 |
| ATSIN062 | 7.63 | J | 140 | 3174 | 24.2 |
| ATSIN063 | 1.39 | * | 146 | 4533 | 6.29 |
| ATSIN064 | 1.35 | * | 153 | 3910 | 5.29 |
| ATSIN071 | 1.54 | * | 159 | 3416 | 5.25 |
| ATSIN072 | 3.96 | J | 165 | 3117 | 12.3 |
| ATSIN073 | 1.39 | * | 172 | 3404 | 4.72 |
| ATSIN074 | 9.08 | J | 179 | 3168 | 28.8 |
| ATSIN081 | 4.22 | J | 185 | 4258 | 18.0 |
| ATSIN082 | 4.10 | J | 191 | 4717 | 19.3 |
| ATSIN083 | 2.93 | J | 198 | 4687 | 13.7 |
| ATSIN084 | 3.87 | J | 204 | 4817 | 18.6 |
| ATSIN091 | 2.84 | J | 210 | 4624 | 13.1 |
| ATSIN092 | 2.74 | J | 217 | 4815 | 13.2 |
| ATSIN093 | 2.87 | J | 223 | 4552 | 13.1 |
| ATSIN094 | 6.55 | J | 229 | 3513 | 23.0 |
| ATSIN101 | 7.19 | J | 237 | 1263 | 9.08 |
| AVG | 3.80 | | | | |
| STD DEV | 2.26 | | | | |
| WEIGHTED AVG: | 3.60 | | TOTAL INFLUENT: | 92160 | 331 |
| Effluent Data | | | | | |
| ATSEFF043 | 4.85 | J | 96 | 4315 | 20.9 |
| ATSEFF044 | 2.06 | J | 102 | 3949 | 8.14 |
| ATSEFF051 | 2.14 | J | 108 | 3786 | 8.10 |
| ATSEFF052 | 1.09 | * | 115 | 4204 | 4.59 |
| ATSEFF053 | 1.04 | M,* | 121 | 4493 | 4.67 |
| ATSEFF054 | 1.05 | * | 128 | 4014 | 4.23 |
| ATSEFF061 | 1.05 | * | 135 | 4812 | 5.07 |
| ATSEFF062 | 1.03 | * | 140 | 3146 | 3.23 |
| ATSEFF063 | 1.02 | * | 146 | 4478 | 4.56 |
| ATSEFF064 | 2.13 | J | 153 | 4131 | 8.80 |
| ATSEFF071 | 2.87 | J | 159 | 3395 | 9.74 |
| ATSEFF072 | 2.63 | J | 165 | 3161 | 8.3 |
| ATSEFF073 | 10.20 | | 172 | 2773 | 28.29 |
| ATSEFF074 | 1.07 | * | 179 | 3488 | 3.7 |
| ATSEFF081 | 4.09 | J | 185 | 4090 | 16.7 |
| ATSEFF082 | 1.09 | * | 191 | 4560 | 5.0 |
| ATSEFF083 | 1.10 | * | 198 | 4655 | 5.1 |
| ATSEFF084 | 1.09 | * | 204 | 4849 | 5.3 |
| ATSEFF091 | 1.07 | * | 210 | 4486 | 4.8 |
| ATSEFF092 | 1.02 | * | 217 | 5092 | 5.2 |
| ATSEFF093 | 2.09 | W | 223 | 4251 | 8.9 |
| ATSEFF094 | 3.41 | J | 229 | 3613 | 12.3 |
| ATSEFF101 | 3.93 | J | 237 | 1158 | 4.55 |
| AVG | 2.31 | | | | |
| STD DEV | 2.03 | | | | |
| WEIGHTED AVG: | 2.09 | | TOTAL EFFLUENT: | 90900 | 190 |
| | | | MATERIAL LOSS (g): | | 141 |
| | | | % MASS REMOVAL: | | 42 |

FILE NAME: ATSHTPHF

(1) A complete explanation of data qualifiers is provided in Table 4–27

TABLE 4–41. BATS – LOW PENTA TEST — MATERIAL INVENTORY – CHEMICAL OXYGEN DEMAND (COD)

| SAIC # | COD (mg/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | COD/ Period (kg) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN011 | 220 | | 6 | 3719 | 0.82 |
| ATSIN012 | 180 | | 12 | 3739 | 0.67 |
| ATSIN013 | 190 | | 18 | 3431 | 0.65 |
| ATSIN014 | 250 | | 26 | 4894 | 1.2 |
| ATSIN021 | 1100 | | 32 | 3722 | 4.1 |
| ATSIN022 | 140 | | 38 | 3423 | 0.48 |
| ATSIN023 | 170 | | 45 | 4509 | 0.77 |
| ATSIN024 | 2200 | | 51 | 3980 | 8.8 |
| ATSIN031 | 170 | | 57 | 3900 | 0.66 |
| ATSIN032 | 1300 | | 64 | 3731 | 4.9 |
| ATSIN033 | 2100 | | 71 | 4696 | 9.9 |
| ATSIN034 | 160 | | 77 | 3867 | 0.62 |
| ATSIN041 | 170 | | 83 | 3774 | 0.64 |
| ATSIN042 | 190 | | 89 | 4001 | 0.76 |
| AVERAGE | 610 | | | | |
| STD DEV | 722 | | | | |
| WEIGHTED AVG: | 630 | TOTAL INFLUENT: | | 55390 | 35 |
| Effluent Data | | | | | |
| ATSEFF011 | 950 | | 6 | 3572 | 3.4 |
| ATSEFF012 | 130 | | 12 | 3803 | 0.49 |
| ATSEFF013 | 140 | | 18 | 3344 | 0.47 |
| ATSEFF014 | 870 | | 25 | 3441 | 3.0 |
| ATSEFF021 | 710 | | 32 | 3626 | 2.6 |
| ATSEFF022 | 100 | | 38 | 3341 | 0.33 |
| ATSEFF023 | 1100 | | 45 | 4071 | 4.5 |
| ATSEFF024 | 1800 | | 51 | 4016 | 7.2 |
| ATSEFF031 | 110 | | 57 | 3782 | 0.42 |
| ATSEFF032 | 120 | | 64 | 3810 | 0.46 |
| ATSEFF033 | 1200 | | 71 | 4536 | 5.4 |
| ATSEFF034 | 92 | | 77 | 3804 | 0.35 |
| ATSEFF041 | 270 | | 83 | 3806 | 1.0 |
| ATSEFF042 | 150 | | 89 | 3837 | 0.58 |
| AVERAGE | 553 | | | | |
| STD DEV | 531 | | | | |
| WEIGHTED AVG: | 570 | TOTAL EFFLUENT: | | 52790 | 30 |
| | | | MATERIAL LOSS (kg): | | 5 |
| | | | % MASS REMOVAL: | | 13 |

FILE NAME: ATSLCODF

(1) A complete explanation of data qualifiers is provided in Table 4–27

TABLE 4–42. BATS – HIGH PENTA TEST — MATERIAL INVENTORY
CHEMICAL OXYGEN DEMAND (COD)

| SAIC # | COD (mg/L) | Data Qualifiers (1) | Time from Beg. of Test (hr) | Volume during Composite period (L) | COD/ Period (kg) |
|---|---|---|---|---|---|
| Influent Data | | | | | |
| ATSIN043 | 710 | | 96 | 4461 | 3.2 |
| ATSIN044 | 190 | | 102 | 3930 | 0.75 |
| ATSIN051 | 200 | | 108 | 3757 | 0.75 |
| ATSIN052 | 180 | | 115 | 4281 | 0.77 |
| ATSIN053 | 485 | M | 121 | 4670 | 2.3 |
| ATSIN054 | 320 | | 128 | 4156 | 1.3 |
| ATSIN061 | 220 | | 135 | 4938 | 1.1 |
| ATSIN062 | 130 | | 140 | 3174 | 0.41 |
| ATSIN063 | 110 | | 146 | 4533 | 0.50 |
| ATSIN064 | 530 | | 153 | 3910 | 2.1 |
| ATSIN071 | 120 | | 159 | 3416 | 0.41 |
| ATSIN072 | 240 | | 165 | 3117 | 0.75 |
| ATSIN073 | 360 | | 172 | 3404 | 1.2 |
| ATSIN074 | 430 | | 179 | 3168 | 1.4 |
| ATSIN081 | 190 | | 185 | 4258 | 0.81 |
| ATSIN082 | 460 | | 191 | 4717 | 2.2 |
| ATSIN083 | 280 | | 198 | 4687 | 1.3 |
| ATSIN084 | 240 | | 204 | 4817 | 1.2 |
| ATSIN091 | 380 | | 210 | 4824 | 1.8 |
| ATSIN092 | 1000 | | 217 | 4815 | 4.8 |
| ATSIN093 | 380 | | 223 | 4552 | 1.7 |
| ATSIN094 | 240 | | 229 | 3513 | 0.84 |
| ATSIN101 | 310 | | 237 | 1263 | 0.39 |
| AVG | 335 | | | | |
| STD DEV | 202 | | | | |
| WEIGHTED AVG: | 350 | | TOTAL INFLUENT: | 92160 | 32 |
| Effluent Data | | | | | |
| ATSEFF043 | 120 | | 96 | 4315 | 0.52 |
| ATSEFF044 | 170 | | 102 | 3949 | 0.67 |
| ATSEFF051 | 150 | | 108 | 3786 | 0.57 |
| ATSEFF052 | 160 | | 115 | 4204 | 0.67 |
| ATSEFF053 | 115 | M | 121 | 4493 | 0.52 |
| ATSEFF054 | 140 | | 128 | 4014 | 0.56 |
| ATSEFF061 | 120 | | 135 | 4812 | 0.58 |
| ATSEFF062 | 110 | | 140 | 3146 | 0.35 |
| ATSEFF063 | 184 | W | 146 | 4478 | 0.82 |
| ATSEFF064 | 130 | | 153 | 4131 | 0.54 |
| ATSEFF071 | 300 | | 159 | 3395 | 1.0 |
| ATSEFF072 | 420 | | 165 | 3161 | 1.3 |
| ATSEFF073 | 320 | | 172 | 2773 | 0.89 |
| ATSEFF074 | 110 | | 179 | 3488 | 0.38 |
| ATSEFF081 | 140 | | 185 | 4090 | 0.57 |
| ATSEFF082 | 270 | | 191 | 4560 | 1.2 |
| ATSEFF083 | 280 | | 198 | 4655 | 1.3 |
| ATSEFF084 | 160 | | 204 | 4849 | 0.78 |
| ATSEFF091 | 260 | | 210 | 4486 | 1.2 |
| ATSEFF092 | 120 | | 217 | 5092 | 0.61 |
| ATSEFF093 | 170 | | 223 | 4251 | 0.72 |
| ATSEFF094 | 210 | | 229 | 3613 | 0.76 |
| ATSEFF101 | 120 | | 237 | 1158 | 0.14 |
| AVG | 186 | | | | |
| STD DEV | 81 | | | | |
| WEIGHTED AVG: | 180 | | TOTAL EFFLUENT: | 90900 | 17 |
| | | | MATERIAL LOSS (kg): | | 15 |
| | | | % MASS REMOVAL: | | 48 |

FILE NAME: ATSHCODF

(1) A complete explanation of data qualifiers is provided in Table 4–27

#### 4.4.3.3 System Parameters

Field data collected over the course of both tests, including flow, temperature, and pH, are summarized in Tables 4-43 and 4-44.

Influent and effluent flow rate data were collected at two hour intervals over the course of the demonstration test. The measurements were in the form of the depth of water in the water storage tanks as read from a level indicator located outside each tank. Each depth measurement was then converted to a volume measurement using the following equation for horizontal tanks (see Perry and Green, 1984):

$$V = L \cdot R^2 \left[(B/57.3) - (\sin B)(\cos B)\right]$$

$B = \cos^{-1}(1-H/R)$ (radians)
$V$ = volume of liquid ($ft^3$)
$R$ = tank radius (ft)
$L$ = length of tank (ft)
$H$ = depth of liquid (ft)

The change in volume was then calculated from two consecutive volume measurements for the same storage tank. This change in volume divided by the time interval over which the change occurred yields the flow rate.

The flow rates remained very steady for both the influent and the effluent over the entire course of the test. The mean influent flow rate was 10.22±0.80 L/min and 10.35±2.64 L/min in the Low Penta and the High Penta test, respectively. The mean effluent flow rate was 9.94±0.87 L/min and 10.13±2.58 L/min for the two tests, respectively. Any significant changes in flow rate were due to equipment adjustments.

Grab samples for temperature measurements were taken 3 times per day and measured with a previously-calibrated immersion thermometer. The average influent temperatures were 16.5±2.0°C and 14.6±4.0°C and the average effluent temperatures were 25.2±1.6°C and 24.7±1.8°C, in the two tests, respectively. The increase in temperature from influent to effluent may be due to the biodegradation within the reactor or solar heating of the trailer and the system, even though the study was carried out in the Fall.

Measurements of pH were recorded from the on-line pH adjustment system and from grab samples taken 3 times per day using a hand-held pH meter. The vendor had specified a pH of approximately 7.3 as the ideal pH of the system and measurements indicate that this was achievable through the on-line pH adjustment system. The pH of the SW process water over the course of the test was in the range of 6.64-8.03 standard units.

### 4.4.4 Slurry Bio-Reactor Performance

#### 4.4.4.1 Critical Analyses

As noted earlier, a single, 14-day test of the SBR was carried out using fine particle slurry taken during the High Penta Soil Washing test. Table 4-45

TABLE 4–43. BATS FIELD MEASUREMENTS – LOW PENTA TEST

| Date | Time | Time from Beg. of Test (hr) | SAIC # | Flow Rates | | Volume | | pH | | | Temperature | | Tank Switch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Influent (L/min) | Effluent (L/min) | Influent (L) | Effluent (L) | On-Line | Influent | Effluent | Influent (C) | Effluent (C) | Influent | Effluent |
| 09/26/89 | 18:55 | 0.0 | BEGIN SAMPLING | | | | | | | | | | | |
| 09/26/89 | 22:09 | 3.2 | | | | | | 7.24 | 7.34 | | 14.5 | | | |
| 09/26/89 | 22:18 | 3.4 | | | | | | | | 7.83 | | 25.0 | | |
| 09/26/89 | 23:22 | 4.5 | | 10.75 | 10.21 | | | 7.31 | | | | | | |
| 09/27/89 | 00:36 | 5.7 | | 9.62 | 9.84 | | | | | | | | | |
| 09/27/89 | 00:46 | 5.9 | ATSIN/EFF011 | | | 3719 | 3572 | | | | | | | |
| 09/27/89 | 01:25 | 6.5 | | | | | | 7.13 | | | | | | |
| 09/27/89 | 02:34 | 7.7 | | 10.50 | 9.78 | | | | | | | | | |
| 09/27/89 | 03:28 | 8.5 | | | | | | 7.34 | | | | | | |
| 09/27/89 | 04:26 | 9.5 | | 9.71 | 10.11 | | | | | | | | | |
| 09/27/89 | 05:21 | 10.4 | | | | | | 7.25 | | | | | | |
| 09/27/89 | 05:33 | 10.6 | | | | | | | 7.45 | | 14.5 | | | |
| 09/27/89 | 05:40 | 10.75 | | | | | | | | 7.47 | | 25.5 | | |
| 09/27/89 | 07:03 | 12.1 | ATSIN012 | | | 3739 | | | | | | | | |
| 09/27/89 | 07:04 | 12.2 | | 9.67 | 9.70 | | | | | | | | | |
| 09/27/89 | 07:11 | 12.3 | ATSEFF012 | | | | 3803 | | | | | | | |
| 09/27/89 | 07:22 | 12.4 | | | | | | 7.03 | | | | | | |
| 09/27/89 | 09:02 | 14.1 | | | | | | | 7.41 | 7.43 | 14.8 | 25.7 | | |
| 09/27/89 | 09:07 | 14.2 | | | | | | 7.19 | | | | | | |
| 09/27/89 | 11:05 | 16.2 | | | | | | 7.20 | | | | | | |
| 09/27/89 | 11:10 | 16.3 | | | | | | | 7.36 | 7.39 | 17.0 | 23.5 | | |
| 09/27/89 | 11:24 | 16.5 | | 9.52 | 9.87 | | | | | | | | | |
| 09/27/89 | 12:29 | 17.6 | | 9.11 | 8.38 | | | | | | | | | |
| 09/27/89 | 12:40 | 17.8 | | | | | | 7.19 | 7.41 | 7.42 | 18.9 | 24.6 | | |
| 09/27/89 | 12:52 | 18.0 | | | | | | | | | | | 1 | |
| 09/27/89 | 13:02 | 18.1 | ATSIN/EFF013 | | | 3431 | 3344 | | | | | | | |
| 09/27/89 | 14:40 | 19.7 | | | | | | 6.37 | | | | | | |
| 09/27/89 | 16:30 | 21.6 | | 12.17 | 6.34 | | | 7.19 | | | | | | |
| 09/27/89 | 18:28 | 23.5 | | | | | | 7.10 | | | | | | |
| 09/27/89 | 18:30 | 23.6 | | | | | | | | | | | | 4 |
| 09/27/89 | 19:02 | 24.1 | | 11.10 | | | | | | | | | | |
| 09/27/89 | 19:15 | 24.3 | | | | | | | 7.38 | | 17.0 | | | |
| 09/27/89 | 19:24 | 24.5 | | | | | | | | 7.48 | | 26.5 | | |
| 09/27/89 | 20:23 | 25.5 | ATSIN/EFF014 | | | 4894 | 3441 | | | | | | | |
| 09/27/89 | 20:47 | 25.9 | | | | | | 7.16 | | | | | | |
| 09/27/89 | 22:22 | 27.4 | | | | | | 7.14 | | | | | | |
| 09/27/89 | 22:28 | 27.6 | | 9.77 | 10.10 | | | | | | | | | |
| 09/28/89 | 00:30 | 29.6 | | | | | | 7.08 | | | | | | |
| 09/28/89 | 00:56 | 30.0 | | 9.99 | 9.57 | | | | | | | | | |
| 09/28/89 | 02:25 | 31.5 | | | | | | 6.96 | | | | | | |
| 09/28/89 | 02:30 | 31.6 | | 9.35 | 9.61 | | | | | | | | | |
| 09/28/89 | 02:35 | 31.7 | ATSIN/EFF021 | | | 3722 | 3626 | | | | | | | |
| 09/28/89 | 03:04 | 32.2 | | | | | | | 7.50 | 7.46 | 16.0 | 23.0 | | |
| 09/28/89 | 04:23 | 33.5 | | 9.19 | 9.42 | | | 7.23 | | | | | | |
| 09/28/89 | 06:24 | 35.5 | | | | | | 7.21 | | | | | | |
| 09/28/89 | 06:29 | 35.6 | | 9.15 | 8.85 | | | | | | | | | |
| 09/28/89 | 08:25 | 37.5 | | | | | | 7.13 | | | | | | |
| 09/28/89 | 08:40 | 37.8 | ATSIN/EFF022 | | | 3423 | 3341 | | | | | | | |
| 09/28/89 | 10:50 | 39.9 | | 8.25 | | | | 7.31 | | | | | | |
| 09/28/89 | 13:23 | 42.5 | | 10.99 | 9.25 | | | 7.24 | | | | | | |
| 09/28/89 | 13:56 | 43.0 | | | | | | | 7.39 | 7.43 | 19.3 | 29.0 | | |
| 09/28/89 | 15:47 | 44.9 | | 9.63 | 10.22 | | | 7.36 | | | | | | |
| 09/28/89 | 16:55 | 46.0 | ATSIN/EFF023 | | | 4509 | 4071 | | | | | | | |
| 09/28/89 | 18:15 | 47.3 | | 11.31 | 11.70 | | | | | | | | | |
| 09/28/89 | 20:47 | 49.9 | | 11.18 | 10.68 | | | | | | | | | |
| 09/28/89 | 22:00 | 51.1 | ATSIN/EFF024 | | | 3980 | 4016 | | | | | | | |
| 09/28/89 | 22:41 | 51.8 | | 10.86 | 10.37 | | | | | | | | | |
| 09/28/89 | 22:55 | 52.0 | | | | | | | 7.41 | | 18.0 | | | |
| 09/28/89 | 22:59 | 52.1 | | | | | | | | 7.55 | | 26.0 | | |
| 09/29/89 | 00:29 | 53.6 | | 9.92 | | | | 7.31 | | | | | | |
| 09/29/89 | 00:36 | 53.7 | | | 9.85 | | | | | | | | | |
| 09/29/89 | 02:25 | 55.5 | | | | | | 7.24 | | | | | | |
| 09/29/89 | 02:29 | 55.6 | | 10.56 | | | | | | | | | | |
| 09/29/89 | 04:15 | 57.3 | ATSIN/EFF031 | | | 3900 | 3782 | | | | | | | |
| 09/29/89 | 04:34 | 57.7 | | | | | | 7.35 | 7.48 | | 16.0 | | | |

(continued)

TABLE 4–43. BATS FIELD MEASUREMENTS – LOW PENTA TEST

| Date | Time | Time from Beg. of Test (hr) | SAIC # | Flow Rates | | Volume | | pH | | | Temperature | | Tank Switch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Influent (L/min) | Effluent (L/min) | Influent (L) | Effluent (L) | On–Line | Influent | Effluent | Influent (C) | Effluent (C) | Influent | Effluent |
| 09/29/89 | 04:40 | 57.8 | | 10.26 | 10.23 | | | | | 7.44 | | 24.0 | | |
| 09/29/89 | 06:27 | 59.5 | | | | | | 7.32 | | | | | | |
| 09/29/89 | 06:31 | 59.6 | | 9.99 | | | | | | | | | | |
| 09/29/89 | 06:34 | 59.7 | | | 10.37 | | | | | | | | | |
| 09/29/89 | 08:34 | 61.7 | | 10.24 | 10.02 | | | 7.05 | | | | | | |
| 09/29/89 | 10:22 | 63.4 | | | | | | | | | | | 2 | |
| 09/29/89 | 10:30 | 63.6 | ATSIN/EFF032 | | | 3731 | 3810 | | | | | | | |
| 09/29/89 | 11:25 | 64.5 | | | 9.86 | | | 6.85 | | | | | | 3 |
| 09/29/89 | 12:40 | 65.9 | | | | | | | 7.03 | 7.21 | 19.5 | 26.5 | | |
| 09/29/89 | 12:55 | 66.0 | | 10.96 | 10.34 | | | 7.17 | | | | | | |
| 09/29/89 | 15:30 | 68.6 | | 10.86 | 10.61 | | | 7.17 | | | | | | |
| 09/29/89 | 17:41 | 70.8 | ATSIN/EFF033 | | | 4696 | 4536 | | | | | | | |
| 09/29/89 | 18:29 | 71.6 | | 10.77 | 10.77 | | | | | | | | | |
| 09/29/89 | 19:39 | 72.7 | | | | | | 7.36 | | | | | | |
| 09/29/89 | 19:43 | 72.8 | | 10.61 | 9.87 | | | | | | | | | |
| 09/29/89 | 21:30 | 74.6 | | 10.91 | 10.79 | | | 6.91 | | | | | | |
| 09/29/89 | 21:40 | 74.8 | | | | | | | 7.45 | 7.42 | 17.0 | 24.0 | | |
| 09/29/89 | 23:27 | 76.5 | | 9.02 | 10.17 | | | 7.36 | | | | | | |
| 09/29/89 | 23:50 | 76.9 | ATSIN/EFF034 | | | 3867 | 3804 | | | | | | | |
| 09/30/89 | 01:30 | 78.6 | | | | | | 6.18 | | | | | | |
| 09/30/89 | 01:39 | 78.7 | | 9.97 | | | | | | | | | | |
| 09/30/89 | 01:40 | 78.8 | | | 9.90 | | | | | | | | | |
| 09/30/89 | 02:30 | 79.6 | | | | | | | 7.19 | | 12.5 | | | |
| 09/30/89 | 02:35 | 79.8 | | | | | | | | 7.23 | | 24.0 | | |
| 09/30/89 | 03:28 | 80.5 | | | | | | 7.12 | | | | | | |
| 09/30/89 | 03:31 | 80.6 | | 11.01 | 10.19 | | | | | | | | | |
| 09/30/89 | 05:36 | 82.7 | | | | | | 6.75 | | | | | | |
| 09/30/89 | 05:40 | 82.8 | | 10.55 | 11.10 | | | | | | | | | |
| 09/30/89 | 05:45 | 82.8 | | | | | | | | | | | | 4 |
| 09/30/89 | 05:59 | 83.1 | ATSIN/EFF041 | | | 3774 | 3806 | | | | | | | |
| 09/30/89 | 07:26 | 84.5 | | | | | | 7.05 | | | | | | |
| 09/30/89 | 07:29 | 84.6 | | 9.96 | 9.79 | | | | | | | | | |
| 09/30/89 | 09:30 | 86.6 | | 10.65 | 9.99 | | | 7.18 | | | | | | |
| 09/30/89 | 10:48 | 87.9 | | | | | | | | | | | 1 | |
| 09/30/89 | 11:29 | 88.6 | | | | | | 7.36 | | | | | | |
| 09/30/89 | 12:20 | 89.4 | ATSIN/EFF042 | | | 4001 | 3837 | | | | | | | |
| AVERAGE | | | | 10.22 | 9.94 | 3693 | 3771 | | | | 16.71 | 25.19 | | |
| STD DEV | | | | 0.80 | 0.87 | 1069 | 303 | | | | 2.01 | 1.61 | | |

FILENAME: PHASEONE

TABLE 4-44. BATS FIELD MEASUREMENTS – HIGH PENTA TEST

| Date | Time | Time from Beg. of Test (hr) | SAIC # | Flow Rates | | Volume | | pH | | | Temperature | | Tank Switch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Influent (L/min) | Effluent (L/min) | Influent (L) | Effluent (L) | On-Line pH | Influent | Effluent | Influent (C) | Effluent (C) | Influent | Effluent |
| 09/26/89 | 18:55 | 0.0 | BEGIN SAMPLING | | | | | | | | | | | |
| 09/30/89 | 11:29 | 88.6 | | | 10.81 | | | 7.36 | | | | | | |
| 09/30/89 | 13:32 | 90.6 | | 10.88 | 10.83 | | | 7.03 | | | | | | |
| 09/30/89 | 15:32 | 92.6 | | 11.35 | 10.93 | | | 6.34 | | | | | | |
| 09/30/89 | 15:40 | 92.8 | | | | | | | 6.69 | 6.94 | 22.0 | 27.5 | | |
| 09/30/89 | 17:25 | 94.5 | | 10.88 | 10.98 | | | 7.06 | | | | | | |
| 09/30/89 | 18:55 | 96.0 | ATSEFF043 | | | | 4315 | | | | | | | |
| 09/30/89 | 19:01 | 96.1 | ATSIN043 | | | 4461 | | | | | | | | |
| 09/30/89 | 19:35 | 96.7 | | 11.80 | 11.10 | | | 7.09 | | | | | | |
| 09/30/89 | 21:33 | 98.6 | | 10.49 | 10.68 | | | 7.19 | | | | | | |
| 09/30/89 | 22:47 | 99.9 | | | | | | | 7.25 | 6.77 | 20.0 | 24.0 | | |
| 09/30/89 | 23:28 | 100.6 | | 10.30 | 10.51 | | | | | | | | | |
| 09/30/89 | 23:38 | 100.7 | | | | | | 7.26 | | | | | | |
| 10/01/89 | 01:05 | 102.1 | ATSIN/EFF044 | | | 3930 | 3949 | | | | | | | |
| 10/01/89 | 01:30 | 102.6 | | 10.83 | 10.04 | | | 7.30 | | | | | | |
| 10/01/89 | 03:29 | 104.6 | | 9.74 | 10.15 | | | 7.30 | | | | | | |
| 10/01/89 | 04:37 | 105.7 | | | | | | | 6.64 | | 19.0 | | | |
| 10/01/89 | 04:44 | 105.8 | | | | | | | | 6.60 | | 24.0 | | |
| 10/01/89 | 04:46 | 105.9 | | | | | | | | | | | | 3 |
| 10/01/89 | 05:30 | 106.6 | | 10.20 | | | | 7.37 | | | | | | |
| 10/01/89 | 07:12 | 108.3 | ATSIN/EFF051 | | | 3757 | 3786 | | | | | | | |
| 10/01/89 | 07:29 | 108.6 | | 10.50 | 10.64 | | | 7.16 | | | | | | |
| 10/01/89 | 09:36 | 110.7 | | 11.60 | 10.46 | | | 7.18 | | | | | | |
| 10/01/89 | 11:30 | 112.6 | | 10.80 | 11.29 | | | 7.21 | | | | | | |
| 10/01/89 | 13:15 | 114.3 | | | | | | | | | | | 2 | |
| 10/01/89 | 13:40 | 114.8 | ATSIN/EFF052 | | | 4281 | 4204 | | | | | | | |
| 10/01/89 | 14:15 | 115.4 | | | 10.80 | | | 7.36 | | | | | | |
| 10/01/89 | 15:30 | 116.6 | | 11.50 | 11.83 | | | 7.16 | | | | | | |
| 10/01/89 | 15:35 | 116.7 | | | | | | | 7.26 | 7.32 | 19.3 | 28.2 | | |
| 10/01/89 | 17:21 | 118.5 | | 12.01 | 11.45 | | | 7.28 | | | | | | |
| 10/01/89 | 19:27 | 120.6 | | 11.19 | 10.71 | | | 7.24 | | | | | | |
| 10/01/89 | 20:21 | 121.4 | ATSIN/EFF053 | | | 4670 | 4493 | | | | | | | |
| 10/01/89 | 22:00 | 123.1 | | 11.35 | 10.76 | | | 7.14 | | | | | | |
| 10/01/89 | 22:53 | 124.0 | | | | | | | 7.50 | 7.03 | 19.0 | 22.0 | | |
| 10/02/89 | 00:22 | 125.5 | | 11.39 | 11.16 | | | 6.92 | | | | | | |
| 10/02/89 | 01:47 | 126.9 | | 11.40 | 10.75 | | | | | | | | | |
| 10/02/89 | 02:27 | 127.5 | | | | | | 7.17 | | | | | | |
| 10/02/89 | 02:30 | 127.6 | ATSIN/EFF054 | | | 4156 | 4014 | | | | | | | |
| 10/02/89 | 02:55 | 128.0 | | | | | | | 9.19 | | 17.5 | | | |
| 10/02/89 | 03:00 | 128.1 | | | | | | | | 9.07 | | 23.0 | | |
| 10/02/89 | 03:45 | 128.9 | | 11.21 | 10.90 | | | | | | | | | 4 |
| 10/02/89 | 04:25 | 129.5 | | | | | | 7.73 | | | | | | |
| 10/02/89 | 05:38 | 130.7 | | 11.80 | | | | | | | | | | |
| 10/02/89 | 05:40 | 130.8 | | | 10.49 | | | | | | | | | |
| 10/02/89 | 06:30 | 131.6 | | | | | | 7.29 | | | | | | |
| 10/02/89 | 07:27 | 132.5 | | 10.91 | 11.26 | | | | | | | | | |
| 10/02/89 | 08:40 | 133.8 | | 11.53 | 12.02 | | | 7.25 | | | | | | |
| 10/02/89 | 09:45 | 134.8 | ATSIN/EFF061 | | | 4938 | 4812 | | | | | | | |
| 10/02/89 | 10:45 | 135.9 | | 11.04 | 11.04 | | | 7.30 | | | | | | |
| 10/02/89 | 12:30 | 137.6 | | 10.69 | 10.24 | | | 7.26 | | | | | | |
| 10/02/89 | 14:45 | 139.8 | ATSIN/EFF062 | | | 3174 | 3146 | | | | | | | |
| 10/02/89 | 15:15 | 140.4 | | 9.61 | 9.92 | | | 7.24 | | | | | | |
| 10/02/89 | 15:30 | 140.6 | | | | | | | 7.19 | 7.28 | 16.5 | 24.0 | | |
| 10/02/89 | 17:19 | 142.4 | | 13.19 | 13.22 | | | 7.36 | | | | | | |
| 10/02/89 | 19:25 | 144.5 | | 11.08 | 10.75 | | | 7.32 | | | | | | |
| 10/02/89 | 21:17 | 146.4 | ATSIN/EFF063 | | | 4533 | 4478 | | | | | | | |
| 10/02/89 | 21:56 | 147.0 | | 11.56 | 11.62 | | | 7.35 | | | | | | |
| 10/02/89 | 22:03 | 147.1 | | | | | | | 7.03 | | 13.0 | | | |
| 10/02/89 | 22:07 | 147.2 | | | | | | | | 7.00 | | 23.0 | | |
| 10/02/89 | 23:25 | 148.5 | | 11.17 | 10.81 | | | 7.18 | | | | | | |
| 10/03/89 | 00:00 | 149.1 | | | | | | | | | | | 1 | 3 |
| 10/03/89 | 01:29 | 150.6 | | | | | | 7.25 | | | | | | |
| 10/03/89 | 03:25 | 152.5 | | | | | | 7.36 | | | | | | |
| 10/03/89 | 03:28 | 152.6 | | 9.73 | 10.70 | | | | | | | | | |
| 10/03/89 | 03:35 | 152.7 | ATSIN/EFF064 | | | 3910 | 4131 | | | | | | | |

(continued)

TABLE 4-44. BATS FIELD MEASUREMENTS – HIGH PENTA TEST

| Date | Time | Time from Beg. of Test (hr) | SAIC # | Flow Rates | | Volume | | pH | | | Temperature | | Tank Switch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Influent (L/min) | Effluent (L/min) | Influent (L) | Effluent (L) | On-Line pH | Influent | Effluent | Influent (C) | Effluent (C) | Influent | Effluent |
| 10/03/89 | 05:25 | 154.5 | | | | | | 7.25 | | | | | | |
| 10/03/89 | 05:28 | 154.6 | | 9.01 | 9.14 | | | | | | | | | |
| 10/03/89 | 06:52 | 155.9 | | | | | | | 8.64 | | 10.0 | | | |
| 10/03/89 | 06:55 | 156.0 | | | | | | | | 8.34 | | 24.0 | | |
| 10/03/89 | 07:27 | 156.5 | | | | | | 7.08 | | | | | | |
| 10/03/89 | 07:30 | 156.6 | | 9.32 | 8.71 | | | | | | | | | |
| 10/03/89 | 09:45 | 158.8 | ATSIN/EFF071 | | | 3416 | 3395 | | | | | | | |
| 10/03/89 | 10:20 | 159.4 | | | | | | 7.24 | | | | | | |
| 10/03/89 | 10:25 | 159.5 | | 9.06 | 8.76 | | | | | | | | | |
| 10/03/89 | 11:30 | 160.6 | | | 9.21 | | | 7.18 | | | | | | |
| 10/03/89 | 12:15 | 161.3 | | 8.54 | | | | | | | | | | |
| 10/03/89 | 14:05 | 163.2 | | | | | | 7.25 | | | | | | |
| 10/03/89 | 14:10 | 163.3 | | 7.70 | 7.49 | | | | 7.12 | 6.81 | 9.0 | 24.0 | | |
| 10/03/89 | 15:45 | 164.8 | | 7.21 | 7.91 | | | 7.16 | | | | | | |
| 10/03/89 | 16:05 | 165.2 | ATSIN/EFF072 | | | 3117 | 3161 | | | | | | | |
| 10/03/89 | 17:26 | 166.5 | | 9.13 | 8.42 | | | 7.26 | | | | | | |
| 10/03/89 | 19:26 | 168.5 | | 7.20 | 4.12 | | | 7.15 | | | | | | |
| 10/03/89 | 20:25 | 169.5 | | | | | | | | | | | | 4 |
| 10/03/89 | 21:30 | 170.6 | | 7.83 | | | | 7.22 | | | | | | |
| 10/03/89 | 21:44 | 170.8 | | | | | | | 7.32 | | 9.0 | | | |
| 10/03/89 | 21:48 | 170.9 | | | | | | | | 6.87 | | 26.0 | | |
| 10/03/89 | 22:37 | 171.7 | ATSEFF073 | | | | 2773 | | | | | | | |
| 10/03/89 | 22:52 | 172.0 | | | 8.41 | | | 7.34 | | | | | | |
| 10/03/89 | 23:21 | 172.4 | ATSIN073 | | | 3404 | | | | | | | | |
| 10/03/89 | 23:39 | 172.7 | | 7.55 | | | | 7.26 | | | | | | |
| 10/04/89 | 01:25 | 174.5 | | | | | | 7.15 | | | | | | |
| 10/04/89 | 01:28 | 174.6 | | 7.91 | 7.15 | | | | | | | | | |
| 10/04/89 | 03:30 | 176.6 | | 8.45 | 8.72 | | | 7.31 | | | | | | |
| 10/04/89 | 04:05 | 177.2 | | | | | | | 7.65 | | 10.0 | | | |
| 10/04/89 | 04:12 | 177.3 | | | | | | | | 7.60 | | 25.0 | | |
| 10/04/89 | 05:25 | 178.5 | | 10.61 | 10.32 | | | 7.19 | | | | | | |
| 10/04/89 | 05:35 | 178.6 | ATSIN/EFF074 | | | 3166 | 3488 | | | | | | | |
| 10/04/89 | 07:25 | 180.5 | | 10.72 | 10.56 | | | 7.32 | | | | | | |
| 10/04/89 | 08:10 | 181.2 | | | | | | | | | | | 2 | |
| 10/04/89 | 09:33 | 182.7 | | | 11.64 | | | 7.29 | | | | | | |
| 10/04/89 | 11:45 | 184.8 | ATSIN/EFF081 | | | 4258 | 4090 | | | | | | | |
| 10/04/89 | 12:15 | 185.3 | | 12.11 | 11.42 | | | 7.15 | | | | | | |
| 10/04/89 | 14:20 | 187.4 | | 11.98 | 12.09 | | | 7.16 | | | | | | |
| 10/04/89 | 15:00 | 188.1 | | | | | | | 7.12 | 7.08 | 14.0 | 26.0 | | |
| 10/04/89 | 15:40 | 188.8 | | 10.84 | 11.06 | | | 7.21 | | | | | | |
| 10/04/89 | 17:35 | 190.7 | | 13.05 | 12.15 | | | 7.13 | | | | | | |
| 10/04/89 | 18:15 | 191.3 | ATSIN/EFF082 | | | 4717 | 4560 | | | | | | | |
| 10/04/89 | 19:38 | 192.7 | | 12.51 | 12.71 | | | 7.29 | | | | | | |
| 10/04/89 | 20:18 | 193.4 | | | | | | | 7.38 | 6.87 | 11.0 | 23.0 | | |
| 10/04/89 | 21:00 | 194.1 | | | | | | | | | | | | 3 |
| 10/04/89 | 21:25 | 194.5 | | 12.34 | | | | 7.16 | | | | | | |
| 10/04/89 | 23:50 | 196.9 | | 12.26 | 11.95 | | | 7.18 | | | | | | |
| 10/05/89 | 00:35 | 197.7 | ATSIN/EFF083 | | | 4887 | 4655 | | | | | | | |
| 10/05/89 | 01:42 | 198.8 | | 11.96 | 12.20 | | | 7.26 | | | | | | |
| 10/05/89 | 03:30 | 200.6 | | | | | | 7.15 | | | | | | |
| 10/05/89 | 03:33 | 200.6 | | 12.46 | 12.29 | | | | | | | | | |
| 10/05/89 | 05:34 | 202.6 | | | | | | 7.29 | | | | | | |
| 10/05/89 | 05:36 | 202.7 | | 12.34 | 12.83 | | | | | | | | | |
| 10/05/89 | 06:22 | 203.4 | | | | | | | 7.43 | 7.28 | 12.0 | 23.0 | | |
| 10/05/89 | 07:05 | 204.2 | ATSIN/EFF084 | | | 4817 | 4849 | | | | | | | |
| 10/05/89 | 07:38 | 204.7 | | 13.09 | 12.46 | | | 7.06 | | | | | | |
| 10/05/89 | 09:40 | 206.8 | | 12.61 | 12.27 | | | 7.07 | | | | | | |
| 10/05/89 | 11:53 | 209.0 | | 12.89 | 12.64 | | | 7.13 | | | | | | |
| 10/05/89 | 13:05 | 210.1 | ATSIN/EFF091 | | | 4624 | 4486 | | | | | | | |
| 10/05/89 | 14:15 | 211.3 | | | | | | | 7.06 | 6.89 | 14.0 | 27.0 | | |
| 10/05/89 | 14:40 | 211.7 | | | | | | 7.12 | | | | | | |
| 10/05/89 | 14:50 | 211.9 | | 12.33 | | | | | | | | | | |
| 10/05/89 | 15:20 | 212.4 | | | 13.71 | | | | | | | | 1 | |
| 10/05/89 | 15:47 | 212.9 | | | | | | | | | | | | 4 |

(continued)

TABLE 4-44. BATS FIELD MEASUREMENTS – HIGH PENTA TEST

| Date | Time | Time from Beg. of Test (hr) | SAIC # | Flow Rates | | Volume | | pH | | | Temperature | | Tank Switch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Influent (L/min) | Effluent (L/min) | Influent (L) | Effluent (L) | On-Line pH | Influent | Effluent | Influent (C) | Effluent (C) | Influent | Effluent |
| 10/05/89 | 16:40 | 213.7 | | | | | | 7.29 | | | | | | |
| 10/05/89 | 17:28 | 214.6 | | 10.88 | | | | 7.25 | | | | | | |
| 10/05/89 | 19:34 | 216.7 | | 12.88 | | | | 7.25 | | | | | | |
| 10/05/89 | 19:52 | 216.9 | ATSIN/EFF092 | | | 4815 | 5092 | | | | | | | |
| 10/05/89 | 21:26 | 218.5 | | 13.48 | | | | 7.33 | | | | | | |
| 10/05/89 | 21:34 | 218.6 | | | | | | | 7.26 | | 13.0 | | | |
| 10/05/89 | 21:38 | 218.7 | | | | | | | | 6.77 | | 23.0 | | |
| 10/05/89 | 23:27 | 220.5 | | 11.81 | | | | 7.36 | | | | | | |
| 10/06/89 | 01:25 | 222.5 | | | | | | 7.00 | | | | | | |
| 10/06/89 | 01:28 | 222.6 | | 11.87 | 11.71 | | | | | | | | | |
| 10/06/89 | 01:58 | 223.0 | ATSIN/EFF093 | | | 4552 | 4251 | | | | | | | |
| 10/06/89 | 03:25 | 224.5 | | | | | | 6.85 | | | | | | |
| 10/06/89 | 03:27 | 224.5 | | 12.06 | 12.70 | | | | | | | | | |
| 10/06/89 | 05:22 | 226.4 | | 13.25 | 9.88 | | | 6.89 | | | | | | |
| 10/06/89 | 07:25 | 228.5 | | 1.59 | 5.37 | | | 7.19 | | | | | | |
| 10/06/89 | 07:33 | 228.6 | | | | | | | 7.39 | | 12.0 | | | |
| 10/06/89 | 07:35 | 228.7 | | | | | | | | 7.33 | | 27.0 | | |
| 10/06/89 | 08:16 | 229.3 | ATSIN/EFF094 | | | 3513 | 3613 | | | | | | | |
| 10/06/89 | 09:15 | 230.3 | | 2.66 | 1.22 | | | 7.07 | | | | | | |
| 10/06/89 | 12:10 | 233.3 | | 3.88 | 3.09 | | | 7.18 | | | | | | |
| 10/06/89 | 12:30 | 233.6 | | | | | | | 7.21 | 7.18 | 17.0 | 25.0 | | |
| 10/06/89 | 13:30 | 234.6 | | 2.41 | 3.42 | | | 7.17 | | | | | | |
| 10/06/89 | 15:30 | 236.6 | | 2.00 | 2.68 | | | 7.21 | | | | | | |
| 10/06/89 | 15:55 | 237.0 | ATSIN/EFF101 | | | 1263 | 1158 | | | | | | | |
| AVERAGE | | | | 10.33 | 10.14 | 3686 | 3952 | | | | 14.6 | 24.7 | | |
| STD DEV | | | | 2.66 | 2.56 | 1345 | 835 | | | | 4.0 | 1.8 | | |

FILENAME: PHASE TWO

TABLE 4–45. SBR TIME–WEIGHTED MASS & VOLUME BALANCE

| INFLUENT | | | | | | | | EFFLUENT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | VOLUME | MASS | | | | VOLUME | MASS |
| DAY | TIME | DATE | HOURS FROM START | DENSITY g/ml | FLOWRATE ml/sec | PER 24 HRS. L | g | TIME | HOURS FROM START | DENSITY g/ml | PER 24 HRS. L | g |
| START | 12:04 | 10/17/89 | 0.00 | | | | | 12:04 | 0.00 | | | |
| | 14:08 | 10/17/89 | 2.07 | 1.019 | 0.426 | | | 14:08 | 2.07 | 1.019 | | |
| | 02:10 | 10/18/89 | 14.10 | 1.081 | — | | | 02:10 | 14.10 | 1.028 | | |
| 1 | 11:43 | 10/18/89 | 23.66 | | | 31.06 | 31730 | 12:02 | 23.98 | 1.023 | 31.18 | 32050 |
| | 16:00 | 10/18/89 | 27.93 | 1.022 | 0.359 | | | 16:00 | 27.93 | 1.056 | | |
| | 01:45 | 10/19/89 | 37.68 | 1.022 | 0.384 | | | 01:45 | 37.68 | 1.021 | | |
| 2 | 11:58 | 10/19/89 | 47.90 | | | 33.48 | 34200 | 11:53 | 47.82 | 1.039 | 33.64 | 34850 |
| | 13:59 | 10/19/89 | 49.92 | 1.021 | 0.394 | | | 13:59 | 49.92 | 1.031 | | |
| | 01:37 | 10/20/89 | 61.55 | 1.014 | 0.398 | | | 01:37 | 61.55 | 1.031 | | |
| 3 | 11:43 | 10/20/89 | 71.65 | | | 34.09 | 34710 | 11:45 | 71.68 | 1.031 | 33.70 | 34690 |
| | 14:04 | 10/20/89 | 74.00 | 1.022 | 0.400 | | | 14:04 | 74.00 | 1.023 | | |
| | 01:30 | 10/21/89 | 85.43 | 1.018 | 0.407 | | | 01:30 | 85.43 | 0.974 | | |
| 4 | 11:52 | 10/21/89 | 95.81 | | | 36.01 | 36650 | 11:40 | 95.60 | 0.998 | 35.06 | 35060 |
| | 13:55 | 10/21/89 | 97.85 | 1.016 | 0.425 | | | 13:55 | 97.85 | 1.031 | | |
| | 01:55 | 10/22/89 | 109.85 | 1.020 | 0.407 | | | 01:55 | 109.85 | 1.047 | | |
| 5 | 12:04 | 10/22/89 | 120.00 | | | 36.05 | 36710 | 11:49 | 119.76 | 1.039 | 44.59 | 46310 |
| | 13:54 | 10/22/89 | 121.83 | 1.017 | 0.420 | | | 13:54 | 121.83 | 1.024 | | |
| | 02:00 | 10/23/89 | 133.93 | 1.011 | 0.412 | | | 02:00 | 133.93 | 1.033 | | |
| 6 | 11:59 | 10/23/89 | 143.92 | | | 36.06 | 36570 | 11:28 | 143.41 | 1.029 | 25.86 | 26590 |
| | 13:52 | 10/23/89 | 145.80 | 1.017 | 0.427 | | | 13:52 | 145.80 | 1.018 | | |
| | 01:47 | 10/24/89 | 157.72 | 1.022 | 0.412 | | | 01:47 | 157.72 | 1.033 | | |
| 7 | 11:59 | 10/24/89 | 167.92 | | | 36.05 | 36770 | 11:50 | 167.77 | 1.025 | 36.13 | 37100 |
| | 13:59 | 10/24/89 | 169.92 | 1.018 | 0.421 | | | 13:59 | 169.92 | 1.031 | | |
| | 01:45 | 10/25/89 | 181.68 | 1.019 | 0.424 | | | 01:45 | 181.68 | 1.025 | | |
| 8 | 11:44 | 10/25/89 | 191.67 | | | 35.94 | 36590 | 11:16 | 191.20 | 1.028 | 34.87 | 35830 |
| | 13:48 | 10/25/89 | 193.73 | 1.018 | 0.417 | | | 13:48 | 193.73 | 1.028 | | |
| | 01:35 | 10/26/89 | 205.52 | 1.025 | 0.412 | | | 01:35 | 205.52 | 1.029 | | |
| 9 | 11:48 | 10/26/89 | 215.73 | | | 35.99 | 36710 | 11:34 | 215.50 | 1.029 | 35.22 | 36200 |
| | 13:50 | 10/26/89 | 217.77 | 1.015 | 0.419 | | | 13:50 | 217.77 | 1.023 | | |
| | 01:15 | 10/27/89 | 229.18 | 1.023 | 0.403 | | | 01:15 | 229.18 | 1.026 | | |
| 10 | 11:58 | 10/27/89 | 239.91 | | | 35.35 | 35990 | 11:41 | 239.62 | 1.024 | 34.82 | 35670 |
| | 14:16 | 10/27/89 | 242.20 | 1.014 | 0.407 | | | 14:16 | 242.20 | 1.023 | | |
| | 01:30 | 10/28/89 | 253.43 | 1.014 | 0.403 | | | 01:30 | 253.43 | 1.025 | | |
| 11 | 11:55 | 10/28/89 | 263.85 | | | 34.93 | 35540 | 11:41 | 263.63 | 1.024 | 34.17 | 34950 |
| | 14:09 | 10/28/89 | 266.08 | 1.023 | 0.407 | | | 14:09 | 266.08 | 1.017 | | |
| | 01:20 | 10/29/89 | 277.27 | 1.016 | 0.398 | | | 01:20 | 277.27 | 1.026 | | |
| 12 | 11:44 | 10/29/89 | 287.67 | | | 34.12 | 35030 | 11:37 | 287.55 | 1.022 | 38.66 | 39550 |

(Continued)

TABLE 4–45. SBR TIME-WEIGHTED MASS & VOLUME BALANCE

| INFLUENT | | | | | | | | EFFLUENT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | VOLUME | MASS | | | | VOLUME | MASS |
| DAY | TIME | DATE | HOURS FROM START | DENSITY g/ml | FLOWRATE ml/sec | PER 24 HRS. L | PER 24 HRS. g | TIME | HOURS FROM START | DENSITY g/ml | PER 24 HRS. L | PER 24 HRS. g |
| | 13:58 | 10/29/89 | 289.90 | 1.039 | 0.396 | | | 13:58 | 289.90 | 1.025 | | |
| | 01:20 | 10/30/89 | 301.27 | 1.027 | 0.407 | | | 01:20 | 301.27 | 1.024 | | |
| 13 | 11:51 | 10/30/89 | 311.79 | | | 34.59 | 35690 | 11:36 | 311.54 | 1.025 | 31.49 | 32240 |
| | 14:08 | 10/30/89 | 314.07 | 1.036 | 0.389 | | | 14:08 | 314.07 | 1.019 | | |
| | 01:10 | 10/31/89 | 325.10 | 1.042 | 0.398 | | | 01:10 | 325.10 | 1.026 | | |
| | 09:47 | 10/31/89 | 333.72 | 1.033 | 0.398 | | | 09:47 | 333.72 | 1.029 | | |
| 14 | 11:51 | 10/31/89 | 335.78 | | | 34.31 | 35590 | 11:51 | 335.78 | 1.025 | 35.26 | 36160 |
| TOTAL FOR NINE DAYS | | | 335.78 | | | 314.7 | 320640 | | 335.78 | | 306.5 | 314300 |
| AVERAGE | | | | 1.024 | 0.392 | | | | | 1.026 | | |
| STANDARD DEVIATION | | | | 0.01 | 0.08 | | | | | 0.01 | | |
| RELATIVE STD. DEVIATION (%) | | | | 1.28 | 19.24 | | | | | 1.22 | | |
| VARIANCE | | | | 0.000 | 0.006 | | | | | 0.005 | | |
| (1–(Vin/Vout))*100 (%) | | | | First 9 days of influent compared to last 9 days of effluent | | | | | | | 2.62 | |
| (1–(Min/Mout))*100 (%) | | | | First 9 days of influent compared to last 9 days of effluent | | | | | | | | 1.98 |

FILENAME: TBL4–39

is a temporal tabulation of density and flow rate measurements for both influent and effluent streams. A statistical analysis of the variations in these measurements is included at the bottom. Results of time-weighted average calculations of the volume and mass as well as their respective closure calculations are also shown.

The volumetric flow rate was quite constant at about 0.4 ml/sec (0.38 gph) with less than 1% variation. Since each of the three reactors had a volume of 60 liters, the total SBR volume was 180 liters. At 0.4 ml/sec, the average retention time was approximately 5.2 days. Because the SBR was operated in a continuous feed mode, equalization was presumed to have occurred in each of the three reactors. However, all of the mass of influent introduced on a particular day would not necessarily be accounted for in the effluent mass 5 days later. It would instead be most likely to be accounted for over several days with most of the mass being accounted for on day 5. This distribution would depend on reactor volume and flow rate. Relying on past experience, the manufacturer contends that the more stages that are arranged in series, the more the system approaches true plug flow conditions. Nevertheless, for purposes of this study, true plug flow operation was assumed, i.e., all influent mass corresponded to all the effluent mass measured 5 days later.

In reviewing the analytical data, it is important to keep this 5 day time lag in mind. To properly characterize the performance of the SBR, the influent concentrations on a particular day should be compared to the effluent concentrations measured 5 days later. Both the influent and effluent densities were quite constant at about 1.025 gm/ml with about a 1% variation in the measurements. The total volume and mass figures shown on the bottom are for the first nine days of influent and days 6 through 14, the corresponding nine days, of effluent flow. This is to properly account for the five day residence time of the SBR. Volume and mass balance closure were excellent with a discrepancy of about 2% between influent and effluent, indicating that all mass was properly accounted for.

Penta and PAHs were the two primary contaminants of interest to determine if BioTrol's claim of 90-95% reduction was valid. Because of the high solids content in the slurry (10.5±2.9%), all influent and effluent composited samples were separated into solid and liquid phases before the extractions were performed (see later section on Total Residue for solid/liquid composition of the liquid and solid samples). The extracts from both phases were then recombined for the chemical analyses. Problems with separation of the solid and liquid phases by centrifugation were encountered. It was ultimately decided to incorporate an additional filtration step, but this in turn delayed the subsequent extraction and analyses, resulting in samples exceeding the holding times specified in the QAPjP.

To determine if missed holding times would have an effect on analyte concentrations, a holding time study was done using a limited number of samples. However, it was not sufficiently comprehensive to be conclusive and the effect of missed holding times could not be determined from the limited amount of data generated. Hence, it was not taken into account and data were used as obtained.

Pentachlorophenol (Penta) -- Analytical results for penta in the liquid phase are shown in Table 4-46 and results for the solid phase are presented in Table 4-47. The data are positioned in the tables so that influent data can be compared with the effluent data for 5 days later, based on the retention time in the system. It should be noted that the filtration left some aqueous phase in the solids. Process monitoring for the first five days of operation revealed that the SBR was not functioning as expected and the acclimation period presumably extended beyond day 5. This was primarily due to the fact that influent penta concentrations were higher than anticipated and process parameters had to be adjusted when this was recognized. No influent readings were taken on day 5 because process parameters were still being adjusted. SBR performance comparisons were done beginning with day 1 influent and day 6 effluent. Calculated penta reductions for both liquid and solid phases are plotted in Figure 4-21. Negative reduction values are not shown on Figure 4-21; it is believed that such anomalies were due to incomplete equalization within the SBR reactor vessels, as discussed earlier, and are not representative of SBR performance.

Penta concentrations in the solid phase were approximately two orders of magnitude higher than in the liquid phase. One reason for this may be that penta solubility in water is reported (Merck Index) as about 80 mg/L, but is pH dependent. Additionally, penta concentration for the liquid phase of the influent (Figure 4-22) decreased over the fifteen day test period from 80.5 to ~35 mg/L, whereas the influent penta concentration for the solid phase (Figure 4-23) remained fairly constant.

Considering the results after the extended acclimation period i.e., after day 5, it can be seen from the data in Tables 4-46 and 4-47 and Figure 4-21 that penta reductions remained at around 97% for the liquid phase but continued to increase asymptotically from approximately 65% to 92% for the solid phase, even after 4 days of "steady state" operation (day 6 through day 9). The most likely reason for such performance probably can be traced back to the contaminant concentrations discussed earlier. The contaminant concentration of the liquid phase, being two orders of magnitude less than the concentration of the solid phase, may insure that there are more than enough bacteria to consume just about all of the contaminant. Conversely, the solid phase has such a high contaminant concentration that bacteria must be generated during the acclimation process to produce a population large enough or aggressive enough to consume all the contaminants and/or overcome any toxicity from the high penta concentration. In this case, the bacteria population or its growth rate may limit the biological degradation reaction rate. Alternately, the solid phase may merely serve as a reservoir or ballast assuring a constant penta concentration in the liquid phase until a tolerable, non-inhibitory concentration is reached on the soil.

Table 4-48 summarizes the influent and effluent penta data for both solid and liquid phases. Concentrations were taken from Tables 4-46 and 4-47. Split samples taken on day 8 were averaged. Solid phase and total solid weight fractions were taken from Table 4-65 (shown later). The water weight fraction was calculated by subtracting the total solid weight fraction from 1. Penta concentration in the solid and liquid phases had to be properly apportioned according to their relative masses to evaluate SBR performance accurately. Penta

TABLE 4–46. SBR LIQUID PHASE PENTA DATA (MG/L)

| INFLUENT | | | | EFFLUENT | | | REMOVAL EFF. (%) |
|---|---|---|---|---|---|---|---|
| DAY | SAIC # | PENTA | Q | SAIC # | PENTA | Q | |
| | | | | SBREFF011LSDL | 230 | D | |
| | | | | SBREFF021LSDL | 60 | D | |
| | | | | SBREFF031LSDL | 170 | D | |
| | | | | SBREFF041LSDL | 280 | D | |
| | | | | SBREFF051LSDL | 160 | D | |
| 1 | SBRIN011LS_DL | 71 | D | SBREFF061LSDL | 170 | D | –139 |
| 2 | SBRIN021LS_DL | 88 | DJ | SBREFF071LSDL | 100 | DJ | –14 |
| 3 | SBRIN031LS_DL | 87 | D | SBREFF081LSDL | 67 | D | |
| | | | | | 71 | * | 18 |
| | | | | SBREFF085LSDL–SP01 | 75 | D | |
| 4 | SBRIN041LS_DL | 46 | D | SBREFF091LS | 49 | | –7 |
| 5 | | | | SBREFF101LSDL | 180 | D | |
| 6 | SBRIN061LS_DL | 79 | D | SBREFF111LS | 6.8 | J | 91 |
| 7 | SBRIN071LS_DL | 69 | DJ | SBREFF121LS | 2.2 | J | 97 |
| 8 | SBRIN081LS_DL | 87 | D | SBREFF131LSDL | 2.3 | J+ | |
| | | 59 | * | | | | 96 |
| | SBRIN085LS–SP01 | 43 | | | | | |
| | SBRIN085LS_DL–SP01 | 46 | D | | | | |
| 9 | SBRIN091LS | 48 | | SBREFF141LS | 1.4 | J | 97 |
| 10 | SBRIN101LS_DL | 62 | D | | | | |
| 11 | SBRIN111LS | 32 | | | | | |
| 12 | SBRIN121LS | 37 | | | | | |
| 13 | SBRIN131LS | 59 | D+ | | | | |
| 14 | SBRIN141LS | 30 | | | | | |
| | AVERAGE | 59 | | | 111 | | |
| | STD DEV | 20 | | | 14 | | |

FILENAME: TBL4–42

+ Values interchanged with effluent based upon SAIC's QA officer recommendation after lab. visit.
* Average value for 3 samples
Q Codes: D = diluted sample
J = estimated value

TABLE 4–47 SBR SOLID PHASE PENTA DATA
(MG/Kg)

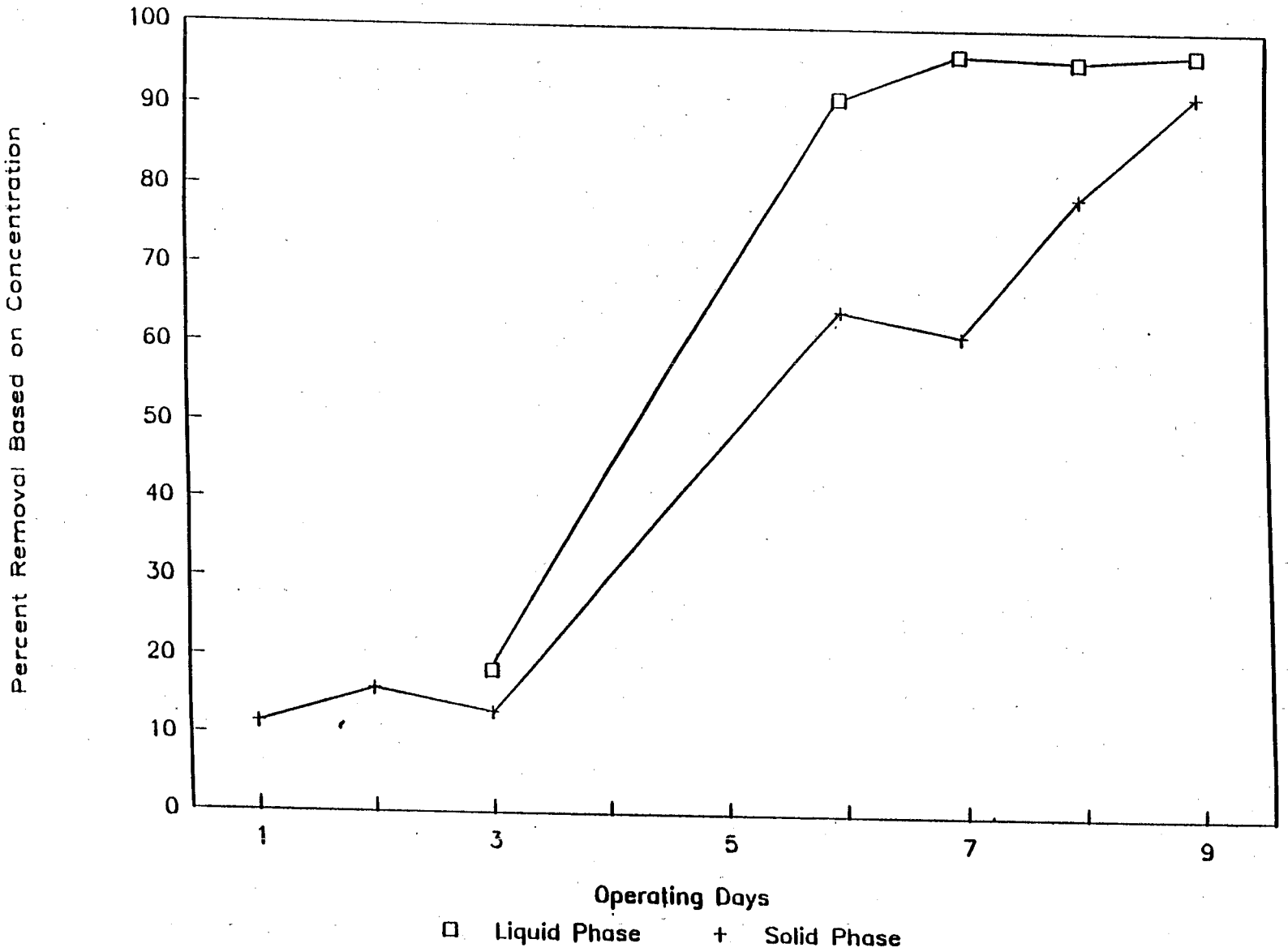
| INFLUENT | | | | EFFLUENT | | | REMOVAL EFF. (%) |
|---|---|---|---|---|---|---|---|
| DAY | SAIC # | PENTA | Q | SAIC # | PENTA | Q | |
| | | | | SBREFF011SSDL | 2,100 | D | |
| | | | | SBREFF021SSDL | 1,600 | D | |
| | | | | SBREFF031SS | 1,300 | | |
| | | | | SBREFF041SSDL | 1,500 | D | |
| | | | | SBREFF051SS | 1,600 | | |
| 1 | SBRIN011SS | 2,600 | | SBREFF061SSDL | 2,300 | D | 12 |
| 2 | SBRIN021SS_DL | 2,500 | D | SBREFF071SSDL | 2,100 | D | 16 |
| 3 | SBRIN031SS_DL | 2,700 | D | SBREFF081SSDL | 2,300 | D | |
| | | | | | 2,350 | * | 100 |
| | | | | SBREFF085SSDL-SP01 | 2,400 | D | |
| 4 | SBRIN041SS_DL | 2,000 | D | SBREFF091SSDL | 2,600 | D | -30 |
| 5 | | | | SBREFF101SSDL | 1,800 | D | |
| 6 | SBRIN061SS_DL | 3,100 | D | SBREFF111SS | 1,100 | | 65 |
| 7 | SBRIN071SS | 1,600 | | SBREFF121SSDL | 620 | D | 61 |
| 8 | SBRIN081SS_DL | 3,400 | D | SBREFF131SS | 660 | | 79 |
| | | 3,150 | * | | | | |
| | SBRIN085SS_DL-SP01 | 2,900 | D | | | | |
| 9 | SBRIN091SS_DL | 3,500 | D | SBREFF141SSDL | 280 | D | 92 |
| 10 | SBRIN101SS_DL | 2,300 | D | | | | |
| 11 | SBRIN111SS_DL | 2,300 | D | | | | |
| 12 | SBRIN121SS_DL | 2,300 | D | | | | |
| 13 | SBRIN131SS_DL | 2,600 | D | | | | |
| 14 | SBRIN141SS_DL | 2,200 | D | | | | |
| | AVERAGE | 2571 | | | 1617 | | |
| | STD DEV | 506 | | | 688 | | |

FILENAME: TBL4–43

* Average value for 2 samples

Q Codes: D = diluted sample

FIGURE 4-21. SLURRY BIO-REACTOR-- PENTA REMOVAL



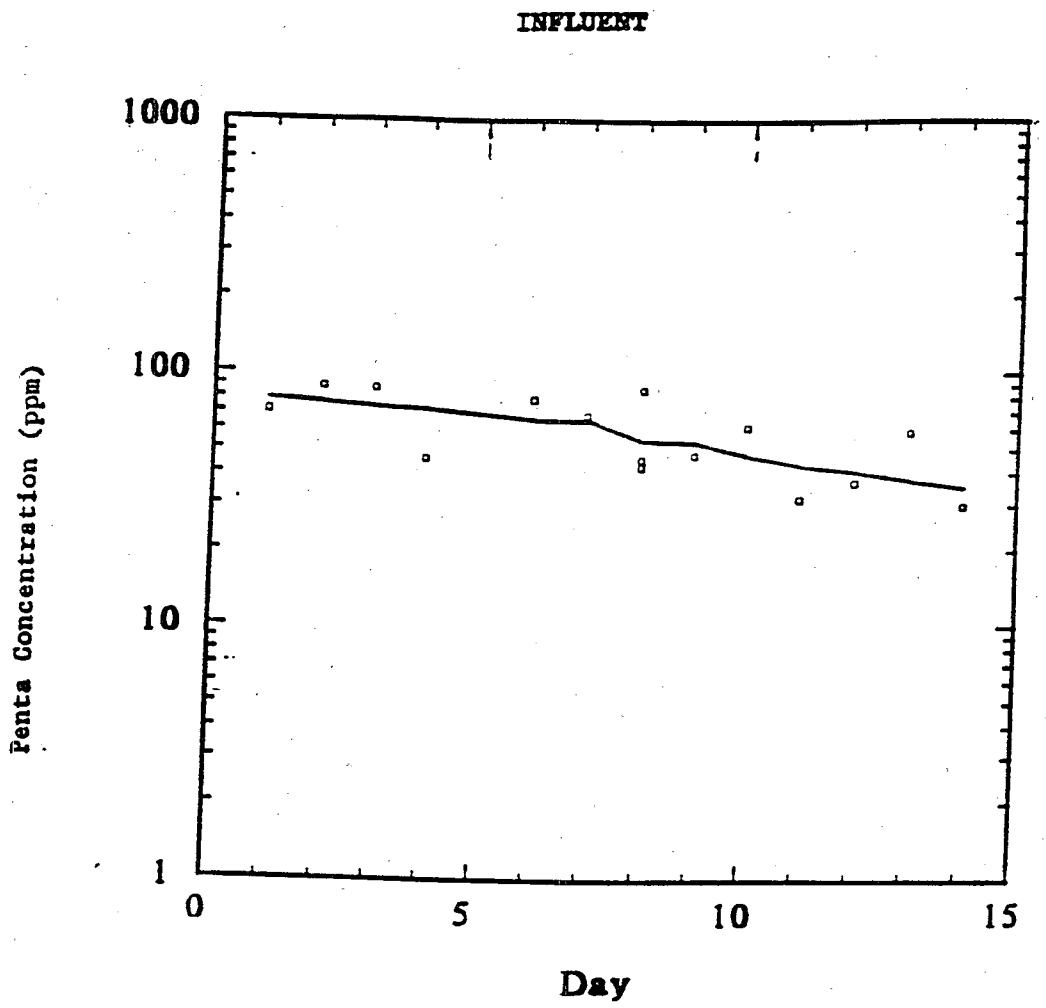



Figure 4-22. SBR Test: Penta in Influent Liquid Phase

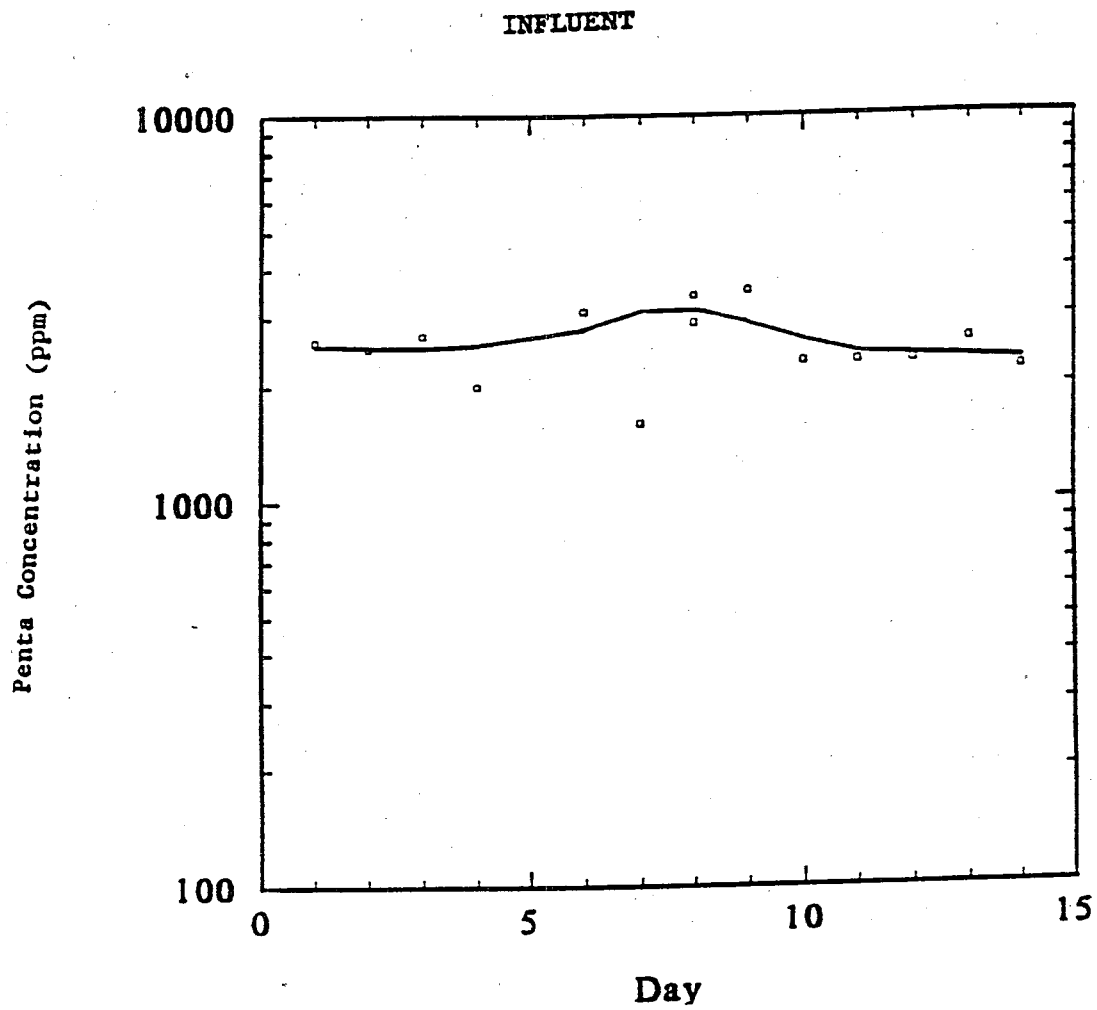



Figure 4-23. SBR Test: Penta in Influent Solid Phase

TABLE 4-48. OVERALL PENTA REDUCTION SBR

INFLUENT

| TEST DAY | Solid Phase | | | Liquid Phase | | TOTAL | | | | | OVERALL PENTA REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract | Penta Mass (gm) | Conc. (ppm) | Penta Mass (gm) | Mass (gm) | Water Wgt. Fract. | Solid Wgt. Fract. | Penta Mass (gm) | Penta Conc. (ppm) | |
| 1 | 2,600 | 0.50 | 47.85 | 71 | 1.60 | 31730 | 0.710 | 0.290 | 49.45 | 1558 | 42 |
| 2 | 2,500 | 0.48 | 17.81 | 88 | 2.71 | 34200 | 0.900 | 0.100 | 20.52 | 600 | 39 |
| 3 | 2,700 | 0.46 | 26.69 | 87 | 2.62 | 34710 | 0.869 | 0.131 | 29.31 | 845 | 35 |
| 4 | 2,000 | 0.53 | 14.11 | 46 | 1.51 | 36650 | 0.898 | 0.102 | 15.62 | 426 | -89 |
| 5 | | | | | | 36710 | | | | | |
| 6 | 3,100 | 0.46 | 15.28 | 79 | 2.71 | 36570 | 0.938 | 0.062 | 17.99 | 492 | 46 |
| 7 | 1,600 | 0.50 | 8.59 | 69 | 2.35 | 36770 | 0.927 | 0.073 | 10.94 | 298 | 48 |
| 8 | 3,150 | * 0.47 | 34.82 | 59 | * 1.85 | 36590 | 0.858 | 0.142 | 36.68 | 1002 | 86 |
| 9 | 3,500 | 0.48 | 36.94 | 48 | 1.52 | 38710 | 0.862 | 0.138 | 38.46 | 1048 | 96 |

* Average value

EFFLUENT

| TEST DAY | Solid Phase | | | Liquid Phase | | TOTAL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract | Penta Mass (gm) | Conc. (ppm) | Penta Mass (gm) | Mass (gm) | Water Wgt. Fract. | Solid Wgt. Fract. | Penta Mass (gm) | Penta Conc. (ppm) |
| 6 | 2,300 | 0.45 | 20.11 | 170 | 3.85 | 26590 | 0.852 | 0.148 | 23.97 | 901 |
| 7 | 2,100 | 0.43 | 9.97 | 100 | 3.51 | 37100 | 0.945 | 0.055 | 13.47 | 363 |
| 8 | 2,350 | * 0.46 | 17.39 | 71 | * 2.30 | 35830 | 0.905 | 0.095 | 19.69 | 550 |
| 9 | 2,600 | 0.47 | 27.64 | 49 | 1.53 | 36200 | 0.862 | 0.138 | 29.16 | 806 |
| 10 | 1,800 | 0.44 | 18.53 | 180 | 5.61 | 35670 | 0.873 | 0.127 | 24.14 | 677 |
| 11 | 1,100 | 0.52 | 9.02 | 6.8 | 0.21 | 34950 | 0.878 | 0.122 | 9.23 | 264 |
| 12 | 620 | 0.51 | 6.01 | 2.2 | 0.08 | 39550 | 0.875 | 0.125 | 6.09 | 154 |
| 13 | 680 | 0.49 | 4.56 | 2.3 | 0.07 | 32240 | 0.895 | 0.105 | 4.63 | 143 |
| 14 | 280 | 0.46 | 1.50 | 1.4 | 0.05 | 38160 | 0.932 | 0.068 | 1.54 | 43 |

FILENAME: TBL4-44

mass for the solid phase was calculated by dividing the concentration of penta in the solid phase by the solid phase weight fraction and then multiplying by the total solid weight fraction and the total mass. A sample calculation for the solid phase measurements on the first day follows:

$$\frac{2600 \text{ gm Penta}}{1 \times 10^6 \text{ gm solid phase}} \times 0.29 \frac{\text{gm solid}}{\text{gm waste}} \times 31{,}730 \text{ gm waste} = 47.85 \text{ gm penta}$$

$$0.5 \frac{\text{gm solid}}{\text{gm solid phase}}$$

Penta mass for the liquid phase was calculated by multiplying the liquid phase penta concentration by the water weight fraction and the total mass. A sample calculation for the first day liquid phase influent measurements follows:

$$\frac{71 \text{ gm penta}}{1 \times 10^6 \text{ gm water}} \times 0.71 \frac{\text{gm water}}{\text{gm waste}} \times 31{,}730 \text{ gm waste} = 1.60 \text{ gm penta}$$

The total penta mass was calculated by summing the penta mass of the solid and liquid phases. Total penta concentration was calculated by dividing the total penta mass by the total mass and multiplying by a million to get ppm. Overall penta reduction was calculated by subtracting the ratio of effluent to influent total penta concentration from 1 and multiplying by 100. The results are plotted in Figure 4-24. Table 4-48 confirms that the majority of the penta is found in the solid phase. Hence, the behavior of the solid weight fraction has a significant influence on penta removal. This influence has been taken into account by the calculation procedure just described and can be observed by comparing Figure 4-24 with Figure 4-21. The high removal efficiencies observed for the liquid phase are tempered by the relatively lower removal efficiencies observed for the solid phase (Figure 4-21) primarily through the solids weight fraction.

As mentioned earlier, the acclimation period extended at least through the first five days of testing and this is shown by the relatively low removal efficiencies (~40%). There is no satisfactory explanation for the negative removal observed on day 4 except that BioTrol was still adjusting process parameters to get optimum performance on day 5. Hence, the SBR was not operating at steady state conditions for the scheduled 14 day test period as prescribed in the Demonstration Test Plan. Had the SBR been allowed to operate for a longer period of time, its performance might have stabilized at a steady state value that would have been more indicative of BioTrol's penta removal claim of 90-95%. It appears, however, that overall removal efficiency for penta (solid and liquid phases) does reach 90% or above based on the last few data and the apparent trend shown in Figure 4-24.

Polynuclear Aromatic Hydrocarbons (PAH) -- For the liquid phase, there were no values above detection limits for either influent or effluent streams. Tables 4-49 and 4-50 present the PAH detection limits reported for the liquid phase samples. Tables 4-51 and 4-52 show the influent and effluent solid phase results for PAHs. It should be observed that the solid phase influent concentrations for the seven PAH compounds of interest are of the same order of magnitude as the penta influent concentration for the liquid phase, discussed earlier. If the

Figure 4-24. Overall Penta Removal

Slurry Bio-Reactor

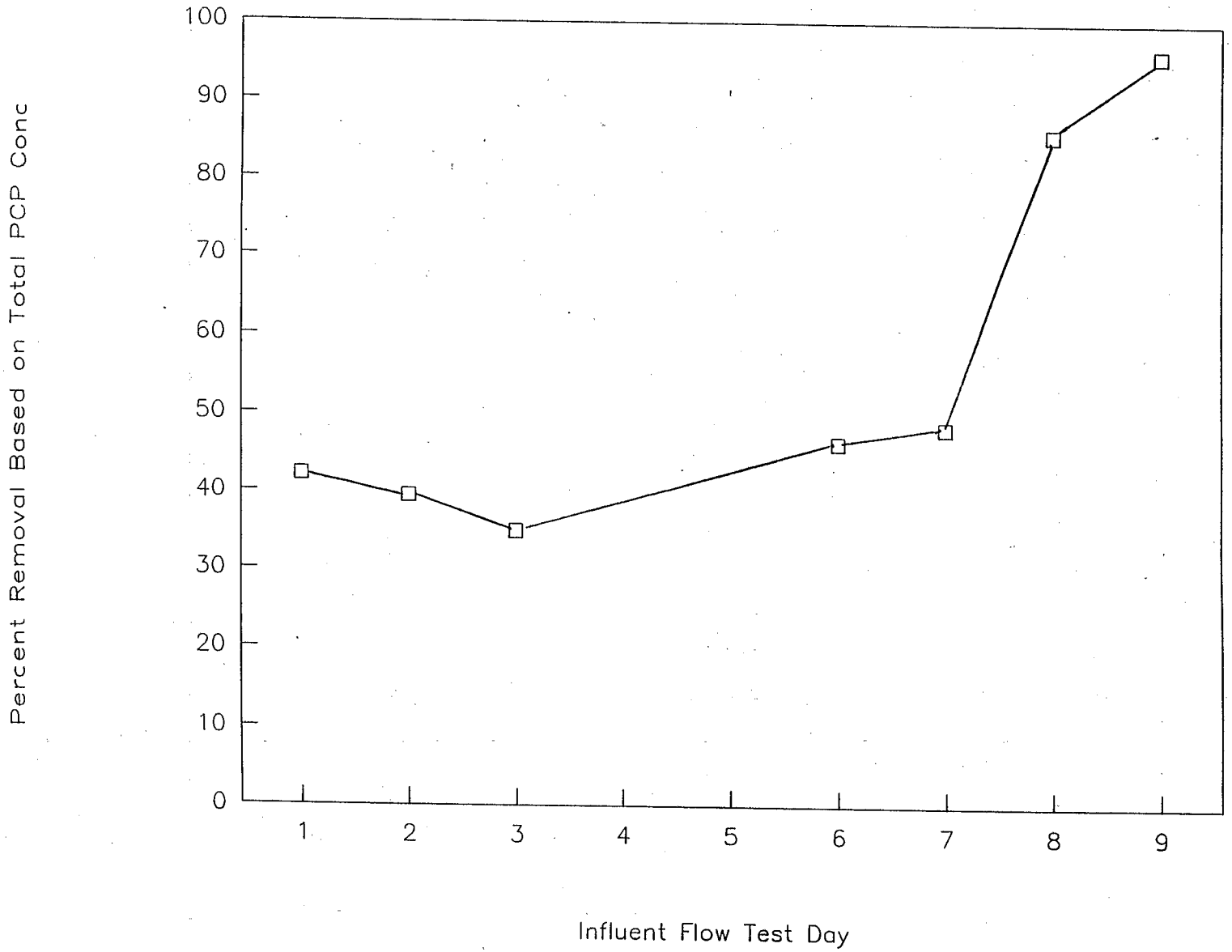


TABLE 4-49. SBR INFLUENT LIQUID PHASE PAH DETECTION LIMITS
(UG/L)

| TEST DAY | SAIC # | Acenaph-thylene | Acenaph-thene | Fluorene | Phenan-threne | Anth-racene | Fluor-anthene | Pyrene | Benzo-(a)-An-thracene | Chrysene | Benzo(b)-Fluor-anthene | Benzo(k)-Fluor-anthene | Benzo(a)-Pyrene | Benzo (g,h,i)-Perylene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SBRIN011LS | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 |
| 2 | SBRIN021LS | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 |
| 3 | SBRIN031LS | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 |
| 4 | SBRIN041LS | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 |
| 5 | | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 6 | SBRIN061LS | 930 | 930 | 930 | 930 | 930 | 930 | 930 | 930 | 930 | 930 | 930 | 930 | 930 |
| 7 | SBRIN071LS | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 8 | SBRIN081LS | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 |
| | SBRIN085LS-SP01 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 | 2900 |
| 9 | SBRIN091LS | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 |
| 10 | SBRIN101LS | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 |
| 11 | SBRIN111LS | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 |
| 12 | SBRIN121LS | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 | 4900 |
| 13 | SBRIN131LS | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| 14 | SBRIN141LS | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 |

FILENAME: TBL4-45

TABLE 4-50. SBR EFFLUENT LIQUID PHASE PAH DETECTION LIMITS
(UG/L)

| TEST DAY | SAIC # | Acenaph-thylene | Acenaph-thene | Fluorene | Phenan-threne | Anth-racene | Fluor-anthene | Pyrene | Benzo-(a)-An-thracene | Chrysene | Benzo(b)-Fluor-anthene | Benzo(k) Fluor-anthene | Benzo(a)-Pyrene | Benzo (g,h,i)-Perylene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SBREFF011LS | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 2 | SBREFF021LS | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 |
| 3 | SBREFF031LS | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 4 | SBREFF041LS | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 |
| 5 | SBREFF051LS | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 |
| 6 | SBREFF061LS | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 |
| 7 | SBREFF071LS | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 |
| 8 | SBREFF081LS | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 |
| | SBREFF085LS-SP01 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 |
| 9 | SBREFF091LS | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 | 5700 |
| 10 | SBREFF101LS | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 | 2800 |
| 11 | SBREFF111LS | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 |
| 12 | SBREFF121LS | 530 | 530 | 530 | 530 | 530 | 530 | 530 | 530 | 530 | 530 | 530 | 530 | 530 |
| 13 | SBREFF131LS | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 | 2600 |
| 14 | SBREFF141LS | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 |

FILENAME: TBL4-46

TABLE 4-51. SBR INFLUENT SOLID PHASE PAH DATA
(mg/kg)

| TEST DAY | SAIC # | Acenaph-thene | Q | Fluor-anthene | Q | Pyrene | Q | Benzo-(a)-An-thracene | Q | Chrysene | Q | Benzo(b)-Fluor-anthene | Q | Benzo(a)-Pyrene | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SBRIN011SS | 190 | U | 390 | | 400 | | 190 | U | 140 | J | 190 | U | 190 | U |
| 2 | SBRIN021SS | 88 | | 480 | | 430 | | 96 | | 180 | | 52 | | 47 | J |
| 3 | SBRIN031SS | 76 | | 450 | | 400 | | 87 | | 160 | | 53 | | 18 | J |
| 4 | SBRIN041SS | 50 | | 280 | | 360 | | 64 | | 110 | | 66 | | 21 | J |
| 5 | | — | | — | | — | | — | | — | | — | | — | |
| 6 | SBRIN061SS | 46 | J | 330 | | 420 | | 74 | | 120 | | 49 | U | 28 | J |
| 7 | SBRIN071SS | 18 | J | 190 | | 270 | | 36 | J | 68 | | 47 | J | 52 | U |
| 8 | SBRIN081SS | 17 | J | 300 | | 490 | | 51 | J | 93 | | 87 | | 31 | J |
| | SBRIN085SS-SP01 | 48 | U | 310 | | 340 | | 39 | J | 82 | | 48 | U | 48 | U |
| 9 | SBRIN091SS | 7.7 | J | 270 | | 570 | | 38 | J | 80 | | 85 | | 32 | J |
| 10 | SBRIN101SS | 49 | U | 240 | | 410 | | 30 | J | 63 | | 70 | | 27 | J |
| 11 | SBRIN111SS | 49 | U | 170 | | 310 | | 49 | U | 43 | J | 50 | | 49 | U |
| 12 | SBRIN121SS | 4.1 | J | 190 | | 380 | | 25 | J | 50 | | 62 | | 23 | J |
| 13 | SBRIN131SS | 50 | U | 260 | | 280 | | 50 | U | 50 | U | 50 | U | 50 | U |
| 14 | SBRIN141SS | 50 | U | 22 | J | 27 | J | 50 | U | 5.2 | J | 50 | U | 50 | U |
| | AVERAGE | 53 | | 277 | | 363 | | 63 | | 89 | | 69 | | 48 | |
| | STD DEV | 44 | | 114 | | 121 | | 41 | | 47 | | 36 | | 41 | |

FILENAME: TBL4-47

Q Codes: U = undetected sample
J = estimated value

TABLE 4–52. SBR EFFLUENT SOLID PHASE PAH DATA
(mg/kg)

| TEST DAY | SAIC # | Acenaph-thene | Q | Fluor-anthene | Q | Pyrene | Q | Benzo-(a)-An-thracene | Q | Chrysene | Q | Benzo(b)-Fluor-anthene | Q | Benzo(a)-Pyrene | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SBREFF011SS | 48 | U | 210 | | 380 | | 54 | | 86 | | 71 | | 48 | U |
| 2 | SBREFF021SS | 49 | U | 210 | | 350 | | 49 | | 87 | | 49 | U | 49 | U |
| 3 | SBREFF031SS | 6.8 | J | 210 | | 340 | | 51 | | 87 | | 61 | | 19 | J |
| 4 | SBREFF041SS | 49 | U | 310 | | 370 | | 66 | | 110 | | 51 | | 49 | U |
| 5 | SBREFF051SS | 53 | U | 250 | | 310 | | 51 | J | 91 | | 53 | U | 53 | U |
| 6 | SBREFF061SS | 49 | U | 220 | | 350 | | 44 | J | 75 | | 68 | | 22 | J |
| 7 | SBREFF071SS | 48 | U | 170 | | 310 | | 28 | J | 53 | | 58 | | 18 | J |
| 8 | SBREFF081SS | 48 | U | 160 | | 290 | | 44 | J | 47 | J | 48 | U | 48 | U |
| | SBREFF085SS-SP01 | 50 | U | 180 | | 290 | | 50 | U | 50 | U | 50 | U | 50 | U |
| 9 | SBREFF091SS | 50 | U | 120 | | 360 | | 50 | U | 39 | J | 65 | | 50 | U |
| 10 | SBREFF101SS | 48 | U | 83 | | 330 | | 35 | J | 39 | J | 57 | | 20 | J |
| 11 | SBREFF111SS | 49 | U | 55 | | 320 | | 27 | J | 30 | J | 59 | | 49 | U |
| 12 | SBREFF121SS | 10 | U | 43 | | 210 | | 26 | | 29 | | 53 | | 36 | |
| 13 | SBREFF131SS | 55 | U | 55 | U | 200 | | 55 | U | 55 | U | 55 | U | 55 | U |
| 14 | SBREFF141SS | 11 | U | 11 | U | 64 | | 9.7 | J | 11 | | 41 | | 18 | |
| | AVERAGE | 42 | | 152 | | 298 | | 43 | | 59 | | 56 | | 39 | |
| | STD DEV | 16 | | 84 | | 80 | | 14 | | 27 | | 8 | | 14 | |

FILENAME: TABLE 4–48

Q Codes: U = undetected sample
J = estimated value

same two order of magnitude relationship that was observed between the solid and liquid phases for the penta data is assumed, then the PAH concentrations for the liquid phase were too low to be detected. Hence, all PAH values in the liquid phase were assumed to be insignificant when compared to the PAH concentrations in the solid phase.

Undetected PAH values reported by the laboratory for the solid phase are shown in Tables 4-51 and 4-52 with a "U" next to the number to indicate that the values are the practical quantitation limit (PQL). The PQL lies in a range somewhere between 5-10 times the standard deviation of the background noise level and is a conservative number to minimize the effect of background noise on the analytical measurement. A less stringent criterion is the method detection limit (MDL) and is normally defined as 3 times the standard deviation of the background noise level. It was decided that a good compromise between using 0 and the reported PQL for undetected values was to use the MDL.

Unfortunately, the laboratory did not routinely report MDLs. Hence, it was necessary to determine a fundamental factor relating PQLs to MDLs. From the above description, this factor had to be between 1.67 and 3.33. The laboratory did, however, report estimated values denoted by the letter "J" as a qualifier. An estimated value is reported when a compound meets identification criteria but the result is less than the PQL and greater than the MDL. Therefore, estimated values would lie somewhere between the MDL and PQL. The lowest estimated values would be the closest to the MDL. A cursory review of several semivolatile compounds for low, medium and high concentration soils selected at random revealed that a factor of 3 could be used to approximately relate MDLs to PQLs. Table 4-53 summarizes the solid phase PAH results using the above interpretation of the data where necessary.

Figures 4-25 through 4-30 show a distinct drop in influent concentration for six of the seven carcinogenic PAHs as the test progressed (negative efficiencies are not included in the graphs). As discussed earlier, the concentrations of these PAHs in the solid phase of the influent are of the same order of magnitude as the concentrations of penta in the liquid phase. The fact that both sets of data (Figure 4-22 and Figures 4-25 through 4-30) show a decrease over the fourteen day test period suggests that microbiological degradation may be occurring in the holding tank prior to the SBR. This is probably caused by bacteria that are indigenous to the soil at the demonstration site. A similar drop in influent penta concentration for the solid phase may not be evident because of the much higher concentration.

Tables 4-54 through 4-60 and Figures 4-31 through 4-37 show the 5 day lag time removal efficiency for seven PAH compounds. Although there is a limited amount of data, some general trends can be observed:

- performance in the first 4 days of operation appeared to peak on day 2 and then drop precipitously;
- after day 5, removal efficiency increased to between 70% and 99% on day 9;

TABLE 4-53. SOLID PHASE PAH RESULTS SUMMARY

**Acenaphthene**

| Day | Influent (ug/kg) | | | Effluent (ug/kg) | | |
|---|---|---|---|---|---|---|
| | Measured | Q | MDL | Measured | Q | MDL |
| 6 | 46000 | J | | | | |
| 7 | 18000 | J | | | | |
| 8 | 17000 | J | | | | |
| 8 | 48000 | U | 16000 | | | |
| 9 | 7700 | J | | | | |
| 10 | 49000 | U | 16333 | | | |
| 11 | 49000 | U | 16333 | 49000 | U | 16333 |
| 12 | 4100 | J | | 10000 | U | 3333 |
| 13 | 50000 | U | 16667 | 55000 | U | 18333 |
| 14 | 50000 | U | 16667 | 11000 | U | 3667 |

**Fluoranthene**

| Day | Influent (ug/kg) | | | Effluent (ug/kg) | | |
|---|---|---|---|---|---|---|
| | Measured | Q | MDL | Measured | Q | MDL |
| 6 | 330000 | | | 220000 | | |
| 7 | 190000 | | | 170000 | | |
| 8 | 300000 | | | 160000 | | |
| 8 | 310000 | | | 180000 | | |
| 9 | 270000 | | | 120000 | | |
| 10 | 240000 | | | 83000 | | |
| 11 | 170000 | | | 55000 | | |
| 12 | 190000 | | | 43000 | | |
| 13 | 280000 | | | 55000 | U | 18333 |
| 14 | 22000 | J | | 11000 | U | 3667 |

**Pyrene**

| Day | Influent (ug/kg) | | | Effluent (ug/kg) | | |
|---|---|---|---|---|---|---|
| | Measured | Q | MDL | Measured | Q | MDL |
| 6 | 420000 | | | 350000 | | |
| 7 | 270000 | | | 310000 | | |
| 8 | 490000 | | | 290000 | | |
| 8 | 340000 | | | 290000 | | |
| 9 | 570000 | | | 380000 | | |
| 10 | 410000 | | | 330000 | | |
| 11 | 310000 | | | 320000 | | |
| 12 | 380000 | | | 210000 | | |
| 13 | 280000 | | | 200000 | | |
| 14 | 27000 | J | | 64000 | | |

**Benzo(a)-Anthracene**

| Day | Influent (ug/kg) | | | Effluent (ug/kg) | | |
|---|---|---|---|---|---|---|
| | Measured | Q | MDL | Measured | Q | MDL |
| 6 | 74000 | | | 44000 | J | |
| 7 | 38000 | J | | 28000 | J | |
| 8 | 51000 | J | | 44000 | J | |
| 8 | 39000 | J | | 50000 | U | 16667 |
| 9 | 38000 | J | | 50000 | U | 16667 |
| 10 | 30000 | J | | 35000 | J | |
| 11 | 49000 | U | 16333 | 27000 | J | |
| 12 | 25000 | J | | 28000 | | |
| 13 | 50000 | U | 16667 | 55000 | U | 18333 |
| 14 | 50000 | U | 16667 | 9700 | J | |

TABLE 4-53. SOLID PHASE PAH RESULTS SUMMARY
(CONTINUED)

Chrysene

| Day | Influent (ug/kg) | | Effluent (ug/kg) | |
|---|---|---|---|---|
| | Measured Q | MDL | Measured Q | MDL |
| 6 | 120000 | | 75000 | |
| 7 | 68000 | | 53000 | |
| 8 | 93000 | | 47000 J | |
| 8 | 82000 | | 50000 U | 16667 |
| 9 | 80000 | | 39000 J | |
| 10 | 63000 | | 39000 J | |
| 11 | 43000 J | | 30000 J | |
| 12 | 50000 | | 29000 | |
| 13 | 50000 U | 27333 | 55000 U | 18333 |
| 14 | 5200 J | | 11000 | |

Benzo(b)-Fluoranthene

| Day | Influent (ug/kg) | | Effluent (ug/kg) | |
|---|---|---|---|---|
| | Measured Q | MDL | Measured Q | MDL |
| 6 | 49000 U | 16333 | 68000 | |
| 7 | 47000 J | | 58000 | |
| 8 | 87000 | | 48000 U | 16000 |
| 8 | 48000 U | 16000 | 50000 U | 16667 |
| 9 | 85000 | | 65000 | |
| 10 | 70000 | | 57000 | |
| 11 | 50000 | | 59000 | |
| 12 | 62000 | | 53000 | |
| 13 | 50000 U | 16667 | 55000 U | 18333 |
| 14 | 50000 U | 16667 | 41000 | |

Benzo(a)-Pyrene

| Day | Influent (ug/kg) | | Effluent (ug/kg) | |
|---|---|---|---|---|
| | Measured Q | MDL | Measured Q | MDL |
| 6 | 28000 J | | 22000 J | |
| 7 | 52000 U | 17333 | 18000 J | |
| 8 | 31000 J | | 48000 U | 16000 |
| 8 | 48000 U | 16000 | 50000 U | 16667 |
| 9 | 32000 J | | 50000 U | 16667 |
| 10 | 27000 J | | 20000 J | |
| 11 | 49000 U | 16333 | 49000 U | 16333 |
| 12 | 23000 J | | 38000 | |
| 13 | 50000 U | 16667 | 55000 U | 18333 |
| 14 | 50000 U | 16667 | 18000 | |

Figure 4-25. SBR Test: Acenaphthene

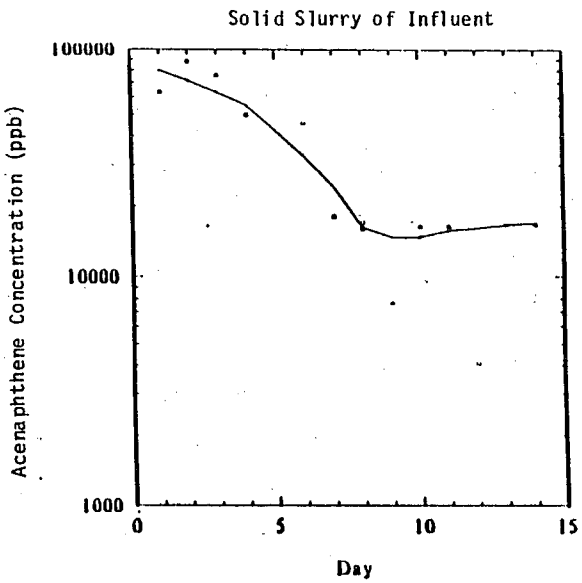



Figure 4-26. SBR Test: Fluoranthene

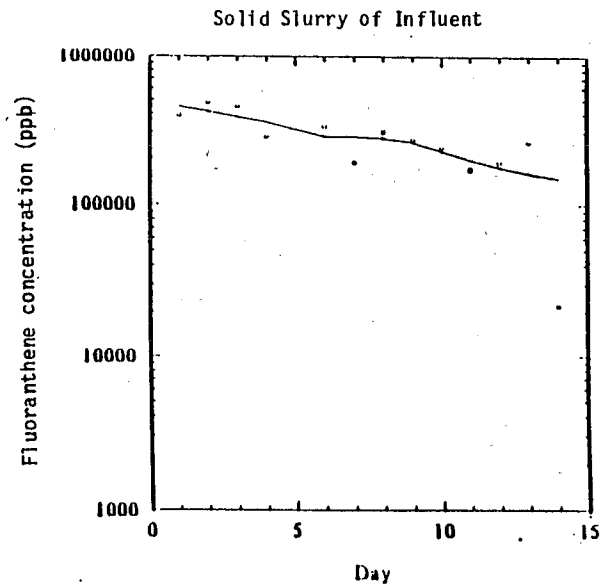



Figure 4-27. SBR Test: Pyrene

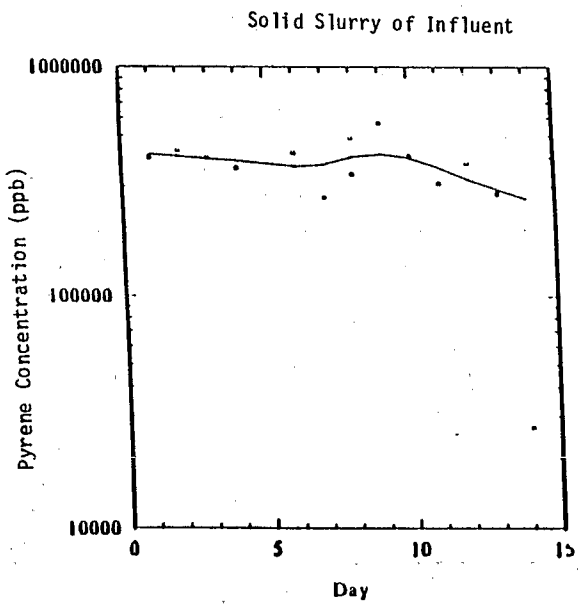



Figure 4-28. SBR Test: Benzo(A)Anthracene

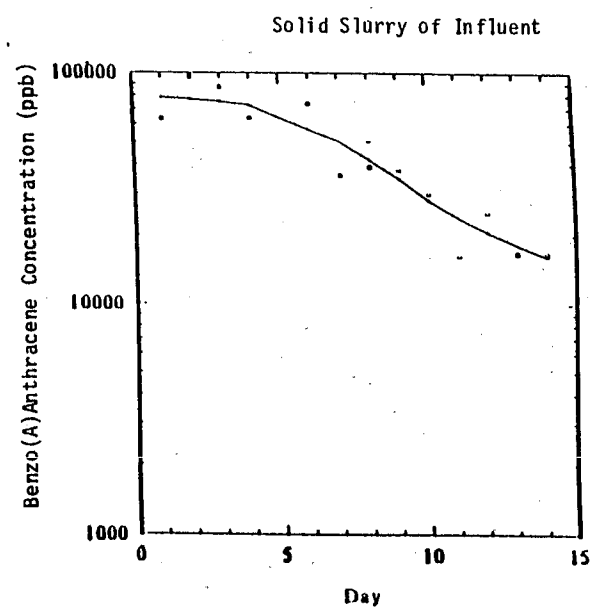


Figure 4-29. SBR Test: Chrysene

Solid Slurry of Influent

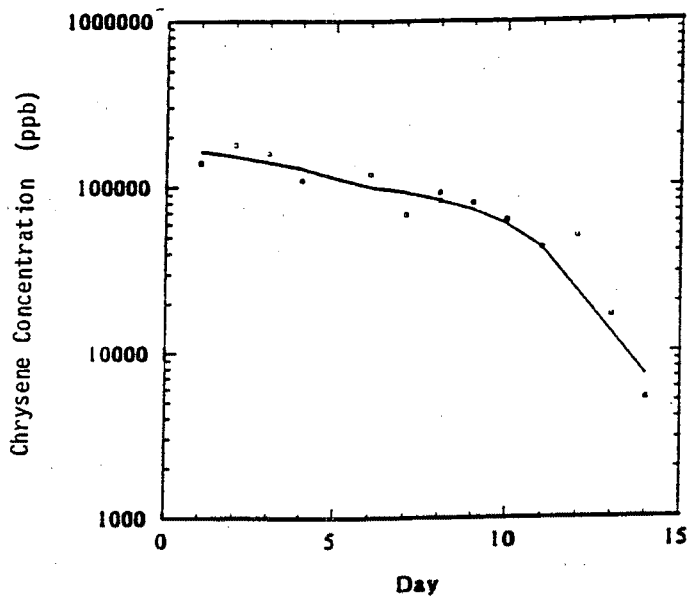



Figure 4-30. SBR Test: Benzo(A)Pyrene

Solid Slurry of Influent

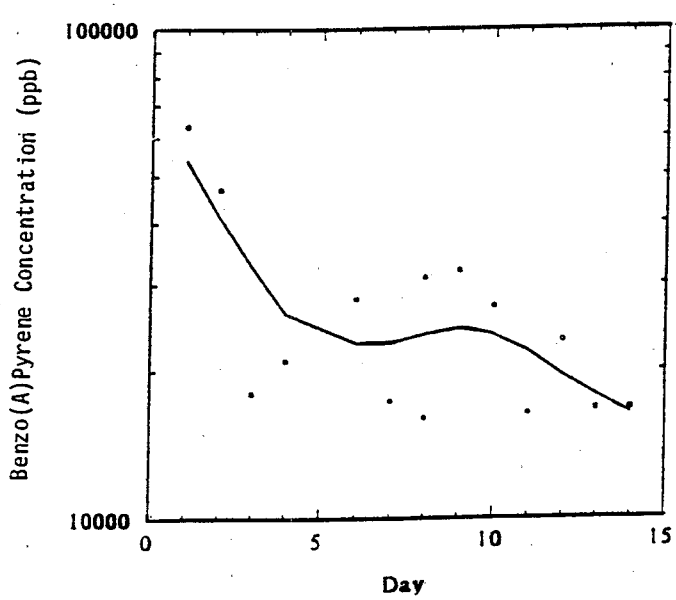


TABLE 4-54. ACENAPHTHENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 63.3 | 0.50 | 1.16 | 31730 | 0.290 | 1.16 | 36.7 | 85 |
| 2 | 88 | 0.48 | 0.63 | 34200 | 0.100 | 0.63 | 18.3 | 89 |
| 3 | 76 | 0.46 | 0.75 | 34710 | 0.131 | 0.75 | 21.6 | 84 |
| 4 | 50 | 0.53 | 0.35 | 36850 | 0.102 | 0.35 | 9.6 | 49 |
| 5 | | | | 36710 | | | | |
| 6 | 46.0 | 0.46 | 0.23 | 36570 | 0.062 | 0.23 | 6.2 | 38 |
| 7 | 18.0 | 0.50 | 0.10 | 36770 | 0.073 | 0.10 | 2.6 | 69 |
| 8 | 16.5 | 0.47 | 0.18 | 36590 | 0.142 | 0.18 | 5.0 | 21 |
| 9 | 7.7 | 0.48 | 0.08 | 36710 | 0.138 | 0.08 | 2.2 | 75 |

EFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | PAH Conc. (ppm) |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | |
| 6 | 16.3 | 0.45 | 0.14 | 26590 | 0.148 | 0.14 | 5 |
| 7 | 16.0 | 0.43 | 0.08 | 37100 | 0.055 | 0.08 | 2 |
| 8 | 16.3 | 0.46 | 0.12 | 35830 | 0.095 | 0.12 | 3 |
| 9 | 16.7 | 0.47 | 0.18 | 36200 | 0.138 | 0.18 | 5 |
| 10 | 16.0 | 0.44 | 0.16 | 35670 | 0.127 | 0.16 | 5 |
| 11 | 16.3 | 0.52 | 0.13 | 34950 | 0.122 | 0.13 | 4 |
| 12 | 3.3 | 0.51 | 0.03 | 39550 | 0.125 | 0.03 | 1 |
| 13 | 18.3 | 0.49 | 0.13 | 32240 | 0.105 | 0.13 | 4 |
| 14 | 3.7 | 0.46 | 0.02 | 36160 | 0.068 | 0.02 | 1 |

FILENAME: TBL4-50

TABLE 4-55. FLUORANTHENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 390 | 0.50 | 7.18 | 31730 | 0.290 | 7.18 | 226.2 | 68 |
| 2 | 480 | 0.48 | 3.42 | 34200 | 0.100 | 3.42 | 100.0 | 78 |
| 3 | 450 | 0.46 | 4.45 | 34710 | 0.131 | 4.45 | 128.2 | 73 |
| 4 | 280 | 0.53 | 1.97 | 36650 | 0.102 | 1.97 | 53.9 | 35 |
| 5 | | | | 36710 | | | | |
| 6 | 330 | 0.46 | 1.63 | 36570 | 0.062 | 1.63 | 44.5 | 71 |
| 7 | 190 | 0.50 | 1.02 | 36770 | 0.073 | 1.02 | 27.7 | 62 |
| 8 | 305 | 0.47 | 3.37 | 36590 | 0.142 | 3.37 | 92.1 | 96 |
| 9 | 270 | 0.48 | 2.85 | 36710 | 0.138 | 2.85 | 77.6 | 99 |

EFFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) |
| 6 | 220 | 0.45 | 1.92 | 26590 | 0.148 | 1.92 | 72 |
| 7 | 170 | 0.43 | 0.81 | 37100 | 0.055 | 0.81 | 22 |
| 8 | 170 | 0.46 | 1.26 | 35830 | 0.095 | 1.26 | 35 |
| 9 | 120 | 0.47 | 1.28 | 36200 | 0.138 | 1.28 | 35 |
| 10 | 83 | 0.44 | 0.85 | 35670 | 0.127 | 0.85 | 24 |
| 11 | 55.0 | 0.52 | 0.45 | 34950 | 0.122 | 0.45 | 13 |
| 12 | 43.0 | 0.51 | 0.42 | 39550 | 0.125 | 0.42 | 11 |
| 13 | 18.3 | 0.49 | 0.13 | 32240 | 0.105 | 0.13 | 4 |
| 14 | 3.7 | 0.46 | 0.02 | 36160 | 0.068 | 0.02 | 1 |

FILENAME: TBL4-51

TABLE 4-56. PYRENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 400 | 0.50 | 7.36 | 31730 | 0.290 | 7.36 | 232.0 | 50 |
| 2 | 430 | 0.48 | 3.06 | 34200 | 0.100 | 3.06 | 89.6 | 56 |
| 3 | 400 | 0.46 | 3.95 | 34710 | 0.131 | 3.95 | 113.9 | 47 |
| 4 | 360 | 0.53 | 2.54 | 36650 | 0.102 | 2.54 | 69.3 | -53 |
| 5 | | | | 36710 | | | | |
| 6 | 420 | 0.46 | 2.07 | 36570 | 0.062 | 2.07 | 56.6 | -33 |
| 7 | 270 | 0.50 | 1.45 | 36770 | 0.073 | 1.45 | 39.4 | -31 |
| 8 | 415 | 0.47 | 4.59 | 36590 | 0.142 | 4.59 | 125.4 | 66 |
| 9 | 570 | 0.48 | 6.02 | 36710 | 0.138 | 6.02 | 163.9 | 94 |

EFFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) |
| 6 | 350 | 0.45 | 3.06 | 26590 | 0.148 | 3.06 | 115 |
| 7 | 310 | 0.43 | 1.47 | 37100 | 0.055 | 1.47 | 40 |
| 8 | 290 | 0.46 | 2.15 | 35830 | 0.095 | 2.15 | 60 |
| 9 | 360 | 0.47 | 3.83 | 36200 | 0.138 | 3.83 | 106 |
| 10 | 330 | 0.44 | 3.40 | 35670 | 0.127 | 3.40 | 95 |
| 11 | 320.0 | 0.52 | 2.62 | 34950 | 0.122 | 2.62 | 75 |
| 12 | 210.0 | 0.51 | 2.04 | 39550 | 0.125 | 2.04 | 51 |
| 13 | 200.0 | 0.49 | 1.38 | 32240 | 0.105 | 1.38 | 43 |
| 14 | 64.0 | 0.46 | 0.34 | 36160 | 0.068 | 0.34 | 9 |

FILENAME: TBL4-52

TABLE 4–57. BENZO(A) ANTHRACENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 63 | 0.50 | 1.16 | 31730 | 0.290 | 1.16 | 36.5 | 60 |
| 2 | 96 | 0.48 | 0.68 | 34200 | 0.100 | 0.68 | 20.0 | 82 |
| 3 | 87 | 0.46 | 0.86 | 34710 | 0.131 | 0.86 | 24.8 | 75 |
| 4 | 64 | 0.53 | 0.45 | 36650 | 0.102 | 0.45 | 12.3 | 60 |
| 5 | | | | 36710 | | | | |
| 6 | 74 | 0.46 | 0.36 | 36570 | 0.062 | 0.36 | 10.0 | 36 |
| 7 | 36 | 0.50 | 0.19 | 36770 | 0.073 | 0.19 | 5.3 | –21 |
| 8 | 45 | 0.47 | 0.50 | 36590 | 0.142 | 0.50 | 13.6 | 71 |
| 9 | 38 | 0.48 | 0.40 | 36710 | 0.138 | 0.40 | 10.9 | 87 |

EFFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) |
| 6 | 44 | 0.45 | 0.38 | 26590 | 0.148 | 0.38 | 14 |
| 7 | 28 | 0.43 | 0.13 | 37100 | 0.055 | 0.13 | 4 |
| 8 | 30.3 | 0.46 | 0.22 | 35830 | 0.095 | 0.22 | 6 |
| 9 | 16.7 | 0.47 | 0.18 | 36200 | 0.138 | 0.18 | 5 |
| 10 | 35 | 0.44 | 0.36 | 35670 | 0.127 | 0.36 | 10 |
| 11 | 27.0 | 0.52 | 0.22 | 34950 | 0.122 | 0.22 | 6 |
| 12 | 26.0 | 0.51 | 0.25 | 39550 | 0.125 | 0.25 | 6 |
| 13 | 18.3 | 0.49 | 0.13 | 32240 | 0.105 | 0.13 | 4 |
| 14 | 9.7 | 0.46 | 0.05 | 36160 | 0.068 | 0.05 | 1 |

FILENAME: TBL4–53

TABLE 4-58. CHRYSENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 140 | 0.50 | 2.58 | 31730 | 0.290 | 2.58 | 81.2 | 70 |
| 2 | 180 | 0.48 | 1.28 | 34200 | 0.100 | 1.28 | 37.5 | 82 |
| 3 | 160 | 0.46 | 1.58 | 34710 | 0.131 | 1.58 | 45.6 | 86 |
| 4 | 110 | 0.53 | 0.78 | 36650 | 0.102 | 0.78 | 21.2 | 46 |
| 5 | | | | 36710 | | | | |
| 6 | 120 | 0.46 | 0.59 | 36570 | 0.062 | 0.59 | 16.2 | 56 |
| 7 | 68 | 0.50 | 0.37 | 36770 | 0.073 | 0.37 | 9.9 | 28 |
| 8 | 88 | 0.47 | 0.97 | 36590 | 0.142 | 0.97 | 26.4 | 85 |
| 9 | 80 | 0.48 | 0.84 | 36710 | 0.138 | 0.84 | 23.0 | 93 |

EFFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) |
| 6 | 75 | 0.45 | 0.66 | 26590 | 0.148 | 0.66 | 25 |
| 7 | 53 | 0.43 | 0.25 | 37100 | 0.055 | 0.25 | 7 |
| 8 | 31.8 | 0.46 | 0.24 | 35830 | 0.095 | 0.24 | 7 |
| 9 | 39 | 0.47 | 0.41 | 36200 | 0.138 | 0.41 | 11 |
| 10 | 39 | 0.44 | 0.40 | 35670 | 0.127 | 0.40 | 11 |
| 11 | 30.0 | 0.52 | 0.25 | 34950 | 0.122 | 0.25 | 7 |
| 12 | 29.0 | 0.51 | 0.28 | 39550 | 0.125 | 0.28 | 7 |
| 13 | 18.3 | 0.49 | 0.13 | 32240 | 0.105 | 0.13 | 4 |
| 14 | 11.0 | 0.46 | 0.06 | 36160 | 0.068 | 0.06 | 2 |

FILENAME: TBL4-54

TABLE 4–59 BENZO(B)–FLUORANTHENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 63 | 0.50 | 1.16 | 31730 | 0.290 | 1.16 | 36.5 | 39 |
| 2 | 52 | 0.48 | 0.37 | 34200 | 0.100 | 0.37 | 10.8 | 32 |
| 3 | 53 | 0.46 | 0.52 | 34710 | 0.131 | 0.52 | 15.1 | 55 |
| 4 | 66 | 0.53 | 0.47 | 36650 | 0.102 | 0.47 | 12.7 | –50 |
| 5 | | | | 36710 | | | | |
| 6 | 16 | 0.46 | 0.08 | 36570 | 0.062 | 0.08 | 2.2 | –530 |
| 7 | 47 | 0.50 | 0.25 | 36770 | 0.073 | 0.25 | 6.9 | –89 |
| 8 | 52 | 0.47 | 0.57 | 36590 | 0.142 | 0.57 | 15.6 | 75 |
| 9 | 85 | 0.48 | 0.90 | 36710 | 0.138 | 0.90 | 24.4 | 75 |

EFFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) |
| 6 | 68 | 0.45 | 0.59 | 26590 | 0.148 | 0.59 | 22 |
| 7 | 58 | 0.43 | 0.28 | 37100 | 0.055 | 0.28 | 7 |
| 8 | 32.7 | 0.46 | 0.24 | 35830 | 0.095 | 0.24 | 7 |
| 9 | 65 | 0.47 | 0.69 | 36200 | 0.138 | 0.69 | 19 |
| 10 | 57 | 0.44 | 0.59 | 35870 | 0.127 | 0.59 | 16 |
| 11 | 59.0 | 0.52 | 0.48 | 34950 | 0.122 | 0.48 | 14 |
| 12 | 53.0 | 0.51 | 0.51 | 39550 | 0.125 | 0.51 | 13 |
| 13 | 18.3 | 0.49 | 0.13 | 32240 | 0.105 | 0.13 | 4 |
| 14 | 41.0 | 0.46 | 0.22 | 36160 | 0.068 | 0.22 | 6 |

FILENAME: TBL4–55

TABLE 4-60. BENZO(A) PYRENE REMOVAL EFFICIENCY

INFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | | OVERALL PAH REDUCTION (%) |
|---|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) | |
| 1 | 63 | 0.50 | 1.16 | 31730 | 0.290 | 1.16 | 36.5 | 80 |
| 2 | 47 | 0.48 | 0.33 | 34200 | 0.100 | 0.33 | 9.8 | 76 |
| 3 | 18 | 0.46 | 0.18 | 34710 | 0.131 | 0.18 | 5.1 | 34 |
| 4 | 21 | 0.53 | 0.15 | 36650 | 0.102 | 0.15 | 4.0 | -21 |
| 5 | | | | 36710 | | | | |
| 6 | 28 | 0.46 | 0.14 | 36570 | 0.062 | 0.14 | 3.8 | -1 |
| 7 | 17 | 0.50 | 0.09 | 36770 | 0.073 | 0.09 | 2.5 | -256 |
| 8 | 24 | 0.47 | 0.26 | 36590 | 0.142 | 0.26 | 7.1 | 45 |
| 9 | 32 | 0.48 | 0.34 | 36710 | 0.138 | 0.34 | 9.2 | 71 |

EFFFLUENT

| TEST DAY | Solid Phase | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|
| | Conc. (ppm) | Solid Wgt.Fract. | PAH Mass (gm) | Mass (gm) | Solid Wgt. Fract. | PAH Mass (gm) | PAH Conc. (ppm) |
| 6 | 22 | 0.45 | 0.19 | 26590 | 0.148 | 0.19 | 7 |
| 7 | 18 | 0.43 | 0.09 | 37100 | 0.055 | 0.09 | 2 |
| 8 | 16.3 | 0.46 | 0.12 | 35830 | 0.095 | 0.12 | 3 |
| 9 | 16.7 | 0.47 | 0.18 | 36200 | 0.138 | 0.18 | 5 |
| 10 | 20 | 0.44 | 0.21 | 35670 | 0.127 | 0.21 | 6 |
| 11 | 16.3 | 0.52 | 0.13 | 34950 | 0.122 | 0.13 | 4 |
| 12 | 36.0 | 0.51 | 0.35 | 39550 | 0.125 | 0.35 | 9 |
| 13 | 18.3 | 0.49 | 0.13 | 32240 | 0.105 | 0.13 | 4 |
| 14 | 18.0 | 0.46 | 0.10 | 36160 | 0.068 | 0.10 | 3 |

FILENAME: TBL4-56

Figure 4-31. Acenaphthene Removal

Slurry Bio-Reactor

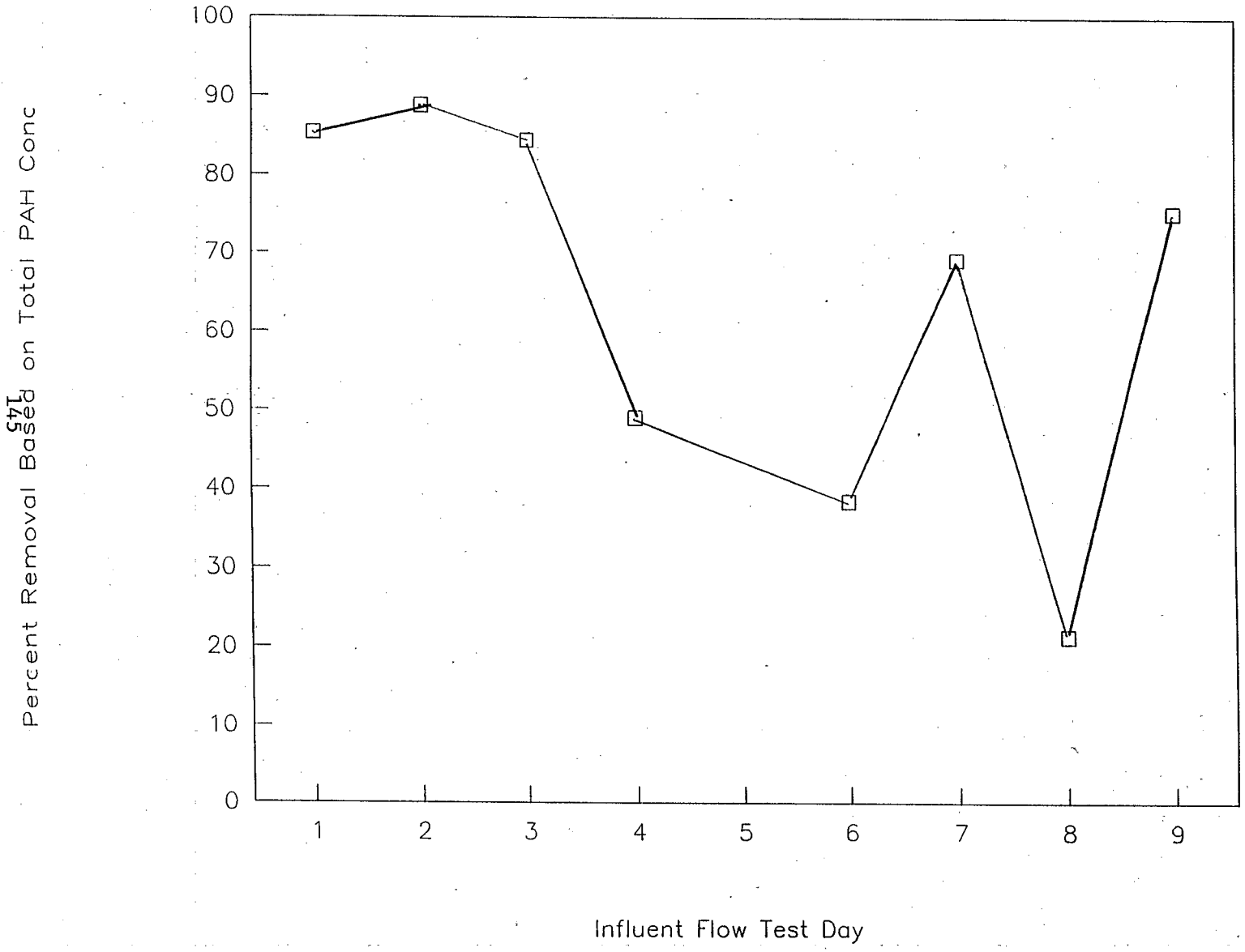
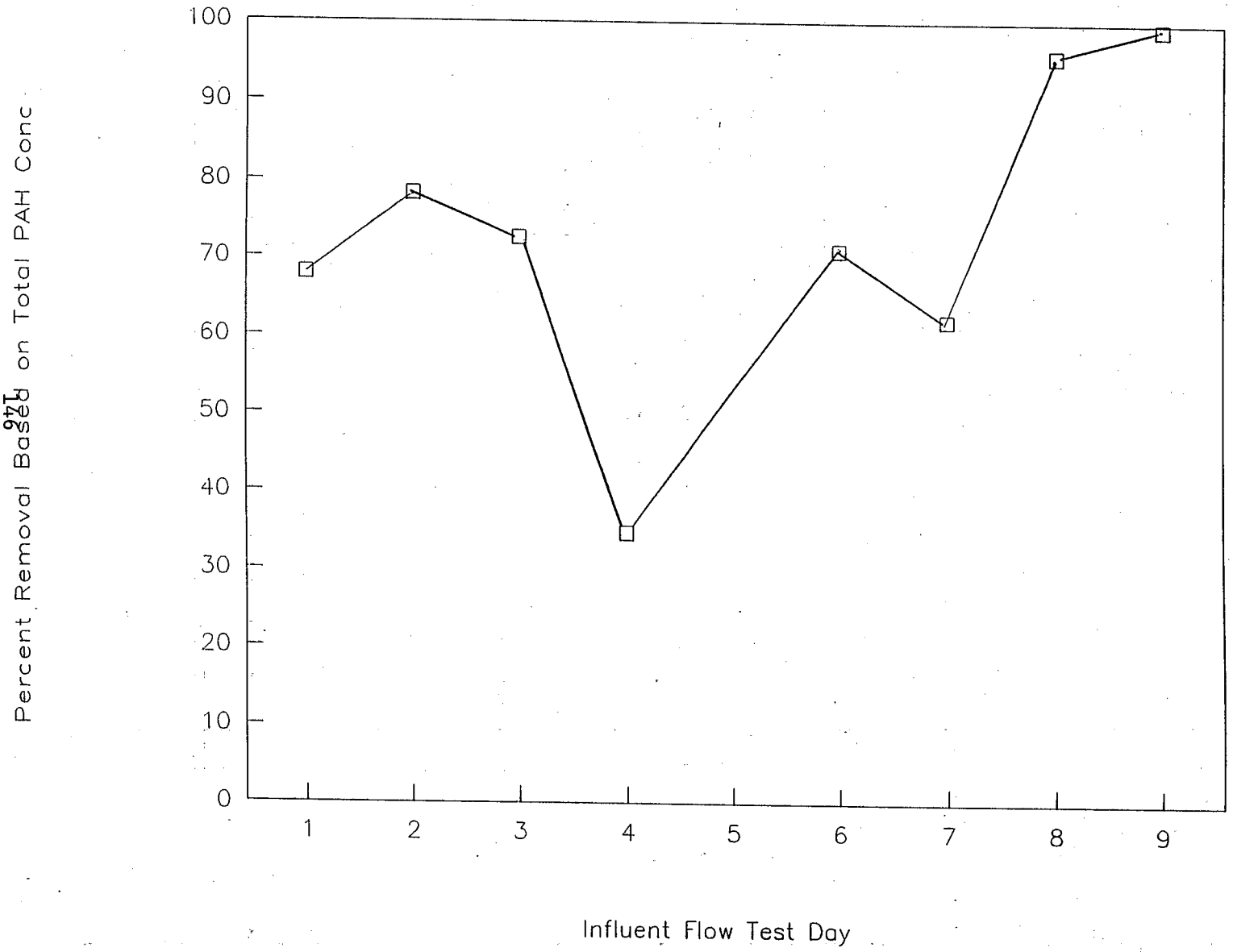


Figure 4-32. Fluoranthene Removal

Slurry Bio-Reactor



# Figure 4–33. Pyrene Removal

Slurry Bio–Reactor

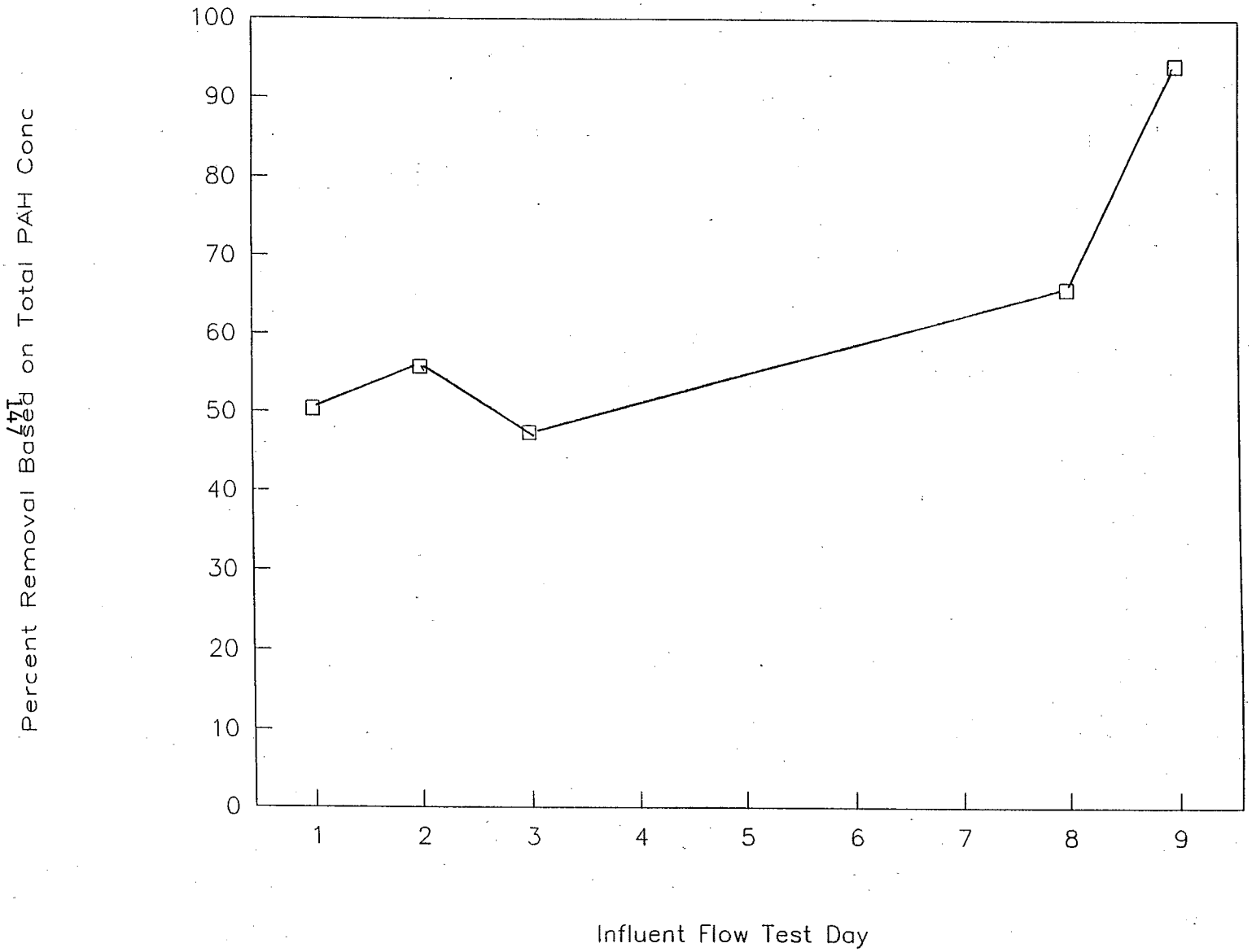
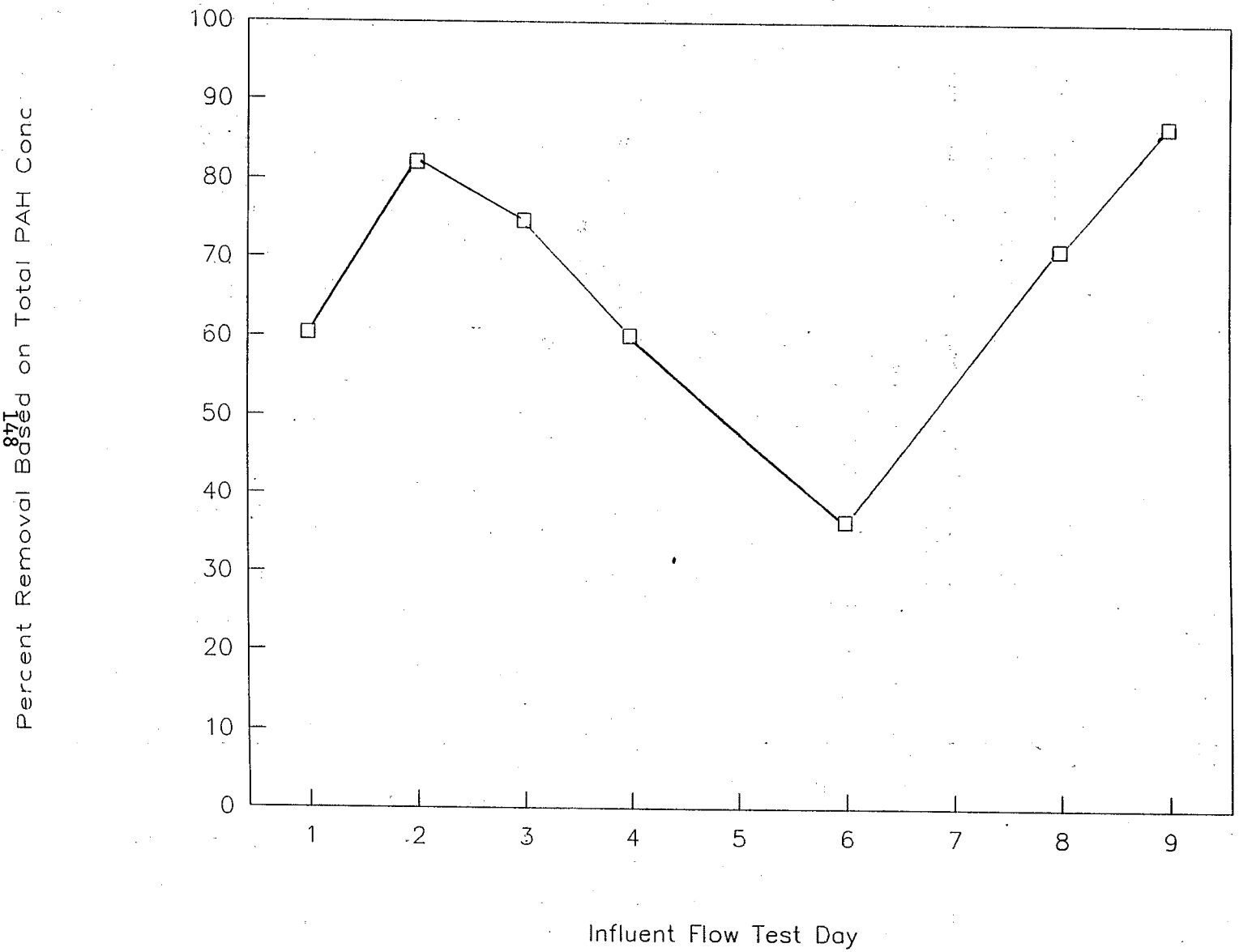


Figure 4-34. Benzo(a)Anthracene Removal

Slurry Bio-Reactor



# Figure 4--35. Chrysene Removal

Slurry Bio-Reactor

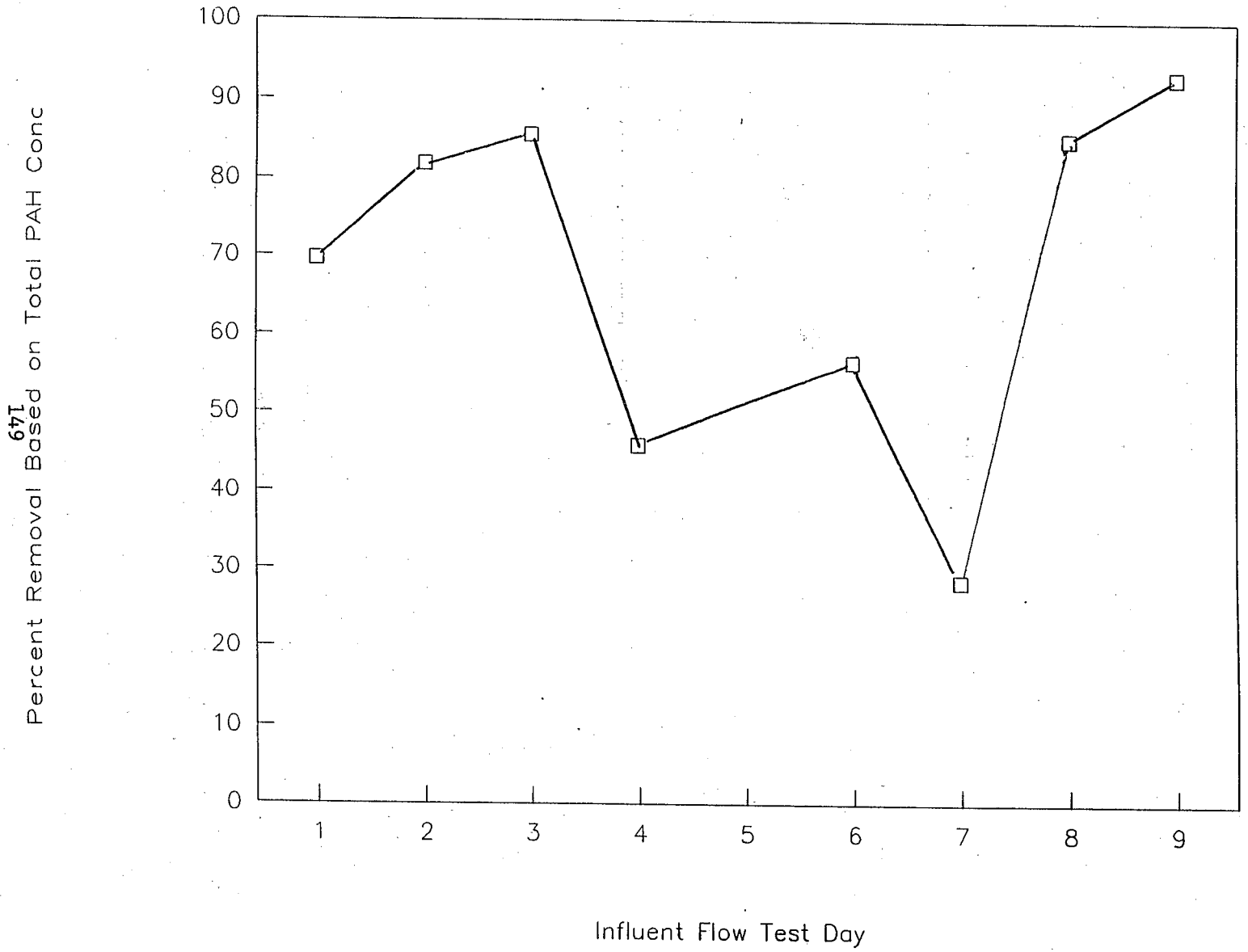


Fig 4-36. Benzo(b)Fluoranthene Removal

Slurry Bio-Reactor

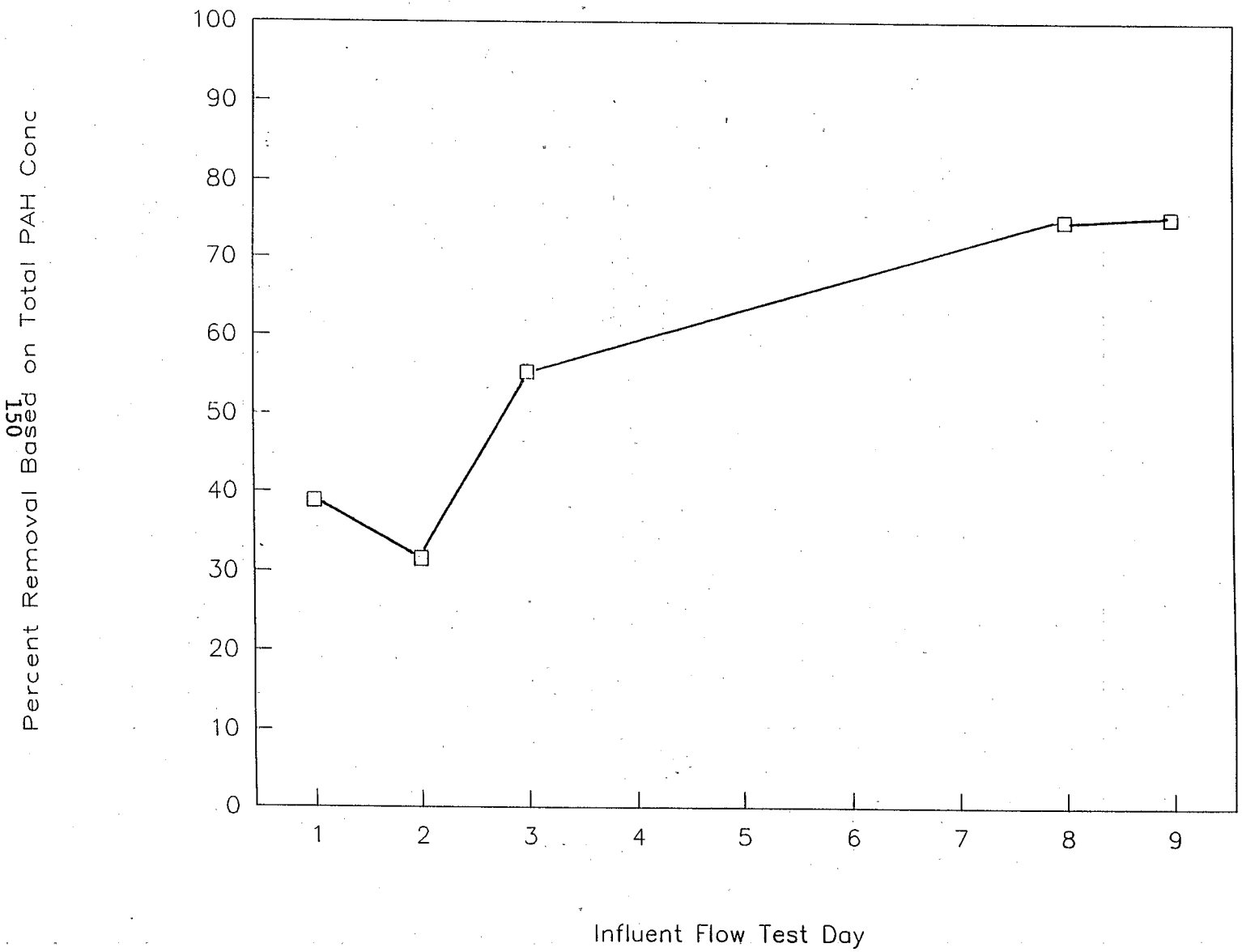
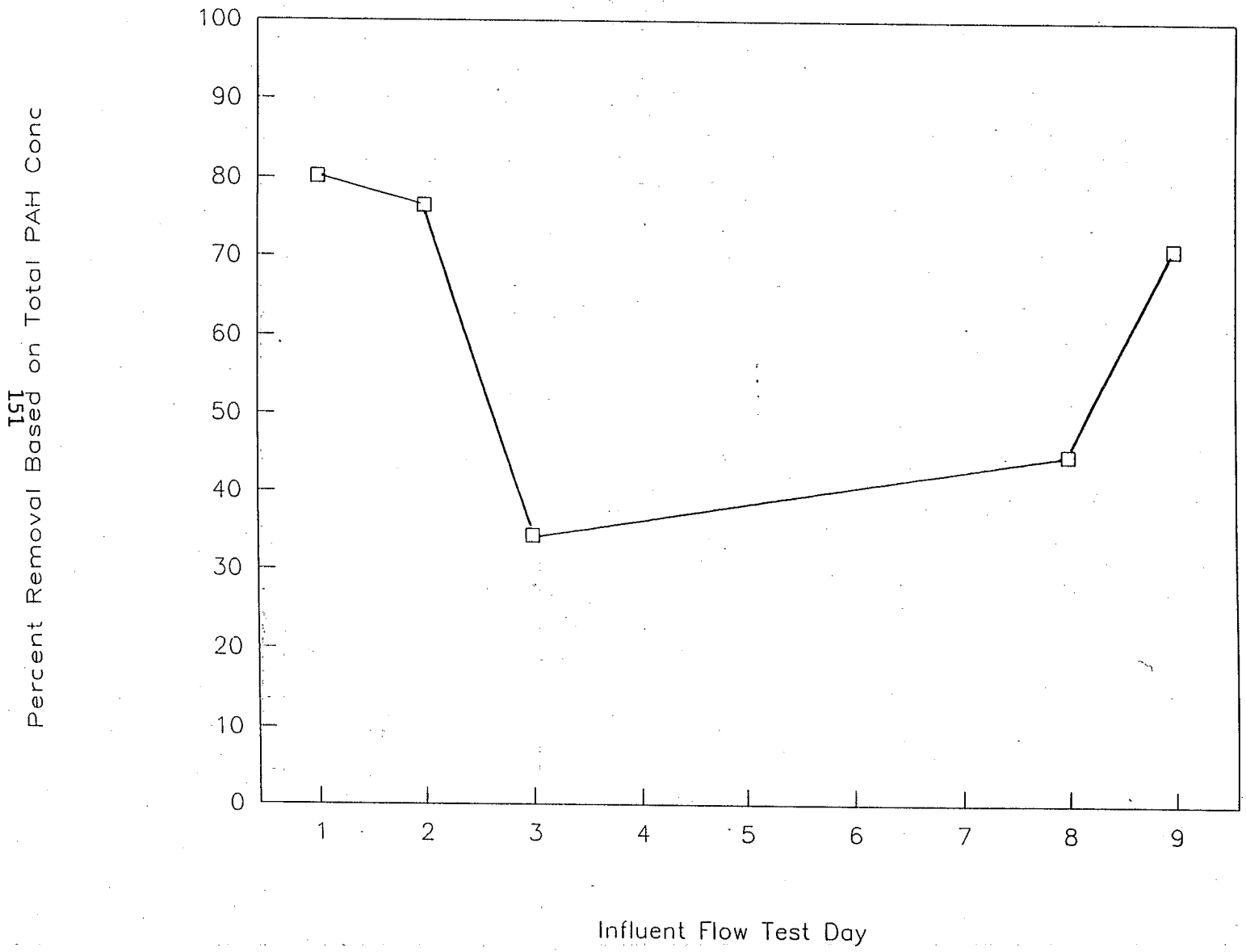


Figure 4-37. Benzo(a)Pyrene Removal

Slurry Bio-Reactor



- for most compounds, there was a noticeable drop in removal efficiency on day 7. This drop was more pronounced for some compounds than for others.

These trends could be a manifestation of the same phenomenon that was observed for penta; i.e., contaminant concentrations are so high that the initial bacteria population is insufficient to consume it and must acclimate and grow. Thereafter, removal efficiency increases with increasing bacterial population. Maximum PAH removal efficiency and PAH removal efficiencies after 9 days of operation at steady state are summarized in Table 4-61. These compounds had the lowest influent concentrations on day 7, accounting for the drop in reduction that was observed. Thereafter, however, a pronounced improvement in reduction efficiency is evident.

Copper, Chromium and Arsenic (CCA) -- Table 4-62 summarizes the influent and effluent CCA data. The first datum point for the influent stream was an outlier and hence was not used in calculating the statistical parameters at the bottom of the Table. In this case, solid and liquid phases were analyzed together.

Variations in the concentration of constituents are comparable between influent and effluent streams. Mass balances between influent for the first 9 days and effluent for the last 9 days of operation for all constituents were within 2%. Therefore, there was no substantial change in CCA within the SBR, as was expected.

#### 4.4.4.2 Other Analyses

Total Recoverable Petroleum Hydrocarbons (TRPH) -- TRPH is a measure of the relatively non-biodegradable oils found in a waste. Table 4-63 presents influent and effluent TRPH data. It should be noted that several points were non-detects. In these instances TRPH concentrations were assumed to be 50% of the detection limit for calculation of statistical parameters. Since the first point for both influent and effluent streams were outliers, they were not used in the statistical calculations shown at the bottom.

The fluctuations in both influent and effluent concentrations are substantial. Average TRPH concentrations show a 30% increase between influent and effluent. This is reflected in a 300% discrepancy for the mass balance when influent for the first 9 days are compared with effluent for the last 9 days of operation. Given the large amount of uncertainty in the data, it is difficult to draw any conclusions.

Chemical Oxygen Demand (COD) -- The chemical oxygen demand is a measure of how much of the organic content of a sample is susceptible to oxidation by a strong chemical oxidant. Table 4-64 summarizes the influent and effluent COD measurements. There is not a significant change in the mean COD concentration between the influent and effluent (2,113 mg/L vs. 2,053 mg/L). The larger variation observed for the influent (39%) than for the effluent (23%) may be attributable to better mixing within the SBR than in the storage tank. The limited amount of data available after day 5 and the large variation in COD concentrations make it difficult to draw definitive conclusions.

TABLE 4-61. PAH REMOVAL SUMMARY

| PAH COMPOUND | MAXIMUM REMOVAL EFFICIENCY (%) | REMOVAL EFFICIENCY ON DAY 9 (%) |
|---|---|---|
| Acenaphthene | 89 | 75 |
| Fluoranthene | 99 | 99 |
| Pyrene | 94 | 94 |
| Benzo(a)Anthracene | 87 | 87 |
| Chrysene | 93 | 93 |
| Benzo(b)Fluoranthene | 75 | 75 |
| Benzo(a)Pyrene | 80 | 71 |

FILENAME: TBL4-57

TABLE 4-62. SBR ARSENIC, CHROMIUM & COPPER MATERIAL BALANCES

| | INFLUENT | | | | | | | | EFFLUENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | SAMPLE ID | ARSENIC (ug/L) | CHROMIUM (ug/L) | COPPER (ug/L) | VOLUME (L) | ARSENIC MASS (mg) | CHROMIUM MASS (mg) | COPPER MASS (mg) | SAMPLE ID | ARSENIC (ug/L) | CHROMIUM (ug/L) | COPPER (ug/L) | VOLUME (L) | ARSENIC MASS (mg) | CHROMIUM MASS (mg) | COPPER MASS (mg) |
| 1 | ++SBR-IN-01-1-CCA | 45700 | 49400 | 54600 | 31.06 | 1419 | 1534 | 1696 | SBR-EFF-01-1-MET | 16500 | 16200 | 16900 | 31.18 | 514 | 505 | 527 |
| 2 | SBR-IN-02-1-CCA | 20100 | 22000 | 24300 | 33.48 | 673 | 737 | 814 | SBR-EFF-02-1-MET | 20600 | 23700 | 23500 | 33.64 | 693 | 797 | 791 |
| 3 | SBR-IN-03-1-CCA | 20200 | 21300 | 23400 | 34.09 | 689 | 726 | 798 | SBR-EFF-03-1-MET | 24300 | 27500 | 27200 | 33.70 | 819 | 927 | 917 |
| 4 | SBR-IN-04-1-CCA | 19500 | 20700 | 22800 | 36.01 | 702 | 745 | 821 | SBR-EFF-04-1-MET | 24000 | 25000 | 26400 | 35.06 | 841 | 877 | 926 |
| 5 | SBR-IN-05-1-CCA | 19100 | 19500 | 21600 | 36.05 | 689 | 703 | 779 | SBR-EFF-05-1-MET | 24700 | 25900 | 27200 | 44.59 | 1101 | 1155 | 1213 |
| 6 | SBR-IN-06-1-CCA | 19600 | 19700 | 21700 | 36.06 | 707 | 710 | 783 | SBR-EFF-06-1-MET | 24200 | 25100 | 26600 | 25.86 | 626 | 649 | 688 |
| 7 | SBR-IN-07-1-CCA | 21200 | 21300 | 23400 | 36.05 | 764 | 768 | 844 | SBR-EFF-07-1-MET | 24900 | 25100 | 26500 | 36.13 | 900 | 907 | 957 |
| 8 | *SBR-IN-08-1-CCA | 20200 | 20100 | 21900 | 35.94 | 726 | 724 | 791 | *SBR-EFF-08-1-MET | 25400 | 27100 | 27300 | 34.87 | 860 | 912 | 929 |
| 8 | *SBR-IN-08-5-CCA | 20200 | 20200 | 22100 | 35.94 | | | | *SBR-EQB-08-5-MET | 23900 | 25200 | 26000 | 34.87 | | | |
| 9 | SBR-IN-09-1-CCA | 20700 | 20700 | 22600 | 35.99 | 745 | 745 | 813 | SBR-EFF-09-1-MET | 23800 | 24700 | 26100 | 35.22 | 838 | 870 | 919 |
| 10 | SBR-IN-10-1-CCA | 15000 | 15300 | 20400 | 35.35 | 530 | 541 | 721 | SBR-EFF-10-1-MET | 23100 | 24700 | 25900 | 34.82 | 804 | 860 | 902 |
| 11 | SBR-IN-11-1-CCA | 20200 | 20800 | 24300 | 34.93 | 706 | 727 | 849 | SBR-EFF-11-1-MET | 23200 | 24300 | 27500 | 34.17 | 793 | 830 | 940 |
| 12 | SBR-IN-12-1-CCA | 15100 | 16300 | 22200 | 34.12 | 515 | 556 | 757 | SBR-EFF-12-1-MET | 23100 | 23300 | 26600 | 38.66 | 893 | 901 | 1028 |
| 13 | SBR-IN-13-1-CCA | 25500 | 25900 | 28900 | 34.59 | 882 | 896 | 1000 | SBR-EFF-13-1-MET | 22100 | 22800 | 25600 | 31.49 | 696 | 718 | 806 |
| 14 | SBR-IN-14-1-CCA | 25600 | 26400 | 30000 | 34.31 | 878 | 906 | 1029 | SBR-EFF-14-1-MET | 23100 | 23600 | 26700 | 35.26 | 815 | 832 | 941 |
| TOTAL (first 9 days) | | | | | | 7114 | 7393 | 8137 | (last 9 days) | | | | | 7224 | 7479 | 8111 |
| AVERAGE | | 20157 | 20729 | 23543 | | | | | | 23127 | 24280 | 25733 | | | | |
| STANDARD DEVIATION | | 2848 | 2847 | 2628 | | | | | | 2105 | 2493 | 2538 | | | | |
| REL. STD. DEV. (%) | | 14.13 | 13.74 | 11.16 | | | | | | 9.10 | 10.27 | 9.86 | | | | |
| VARIANCE | | 8113878 | 8107755 | 6903878 | | | | | | 4432622 | 6216267 | 6440889 | | | | |
| MASS CLOSURE (%) – first 9 days compared to last 9 days | | | | | | | | | | | | | | -1.55 | -1.17 | 0.32 |

FILENAME: TBL4-58

* Mass calculations used average of split sample

TABLE 4-63. SBR TOTAL RECOVERABLE PETROLEUM HYDROCARBON MATERIAL BALANCE

| INFLUENT | | | | | | | EFFLUENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | SAMPLE ID | TRPH (mg/L) | QUALIFER | DETECTION LIMIT (mg/L) | VOLUME (L) | MASS (mg) | SAMPLE ID | TRPH (mg/L) | QUALIFIER | DETECTION LIMIT (mg/L) | VOLUME (L) | MASS (mg) |
| 01 | SBR-IN-01-1-TRPH | 4 | <5X | 2 | 31.06 | 125 | SBR-EFF-01-1-TRPH | 3 | <5X | 2 | 31.18 | 98 |
| 02 | SBR-IN-02-1-TRPH | 46 | ND | 92 | 33.48 | 1540 | SBR-EFF-02-1-TRPH | 448 | <5X | 100 | 33.64 | 15071 |
| 03 | SBR-IN-03-1-TRPH | 50 | ND | 100 | 34.09 | 1705 | SBR-EFF-03-1-TRPH | 50 | ND | 100 | 33.70 | 1685 |
| 04 | SBR-IN-04-1-TRPH | 50 | ND | 100 | 36.01 | 1801 | SBR-EFF-04-1-TRPH | 160 | <5X | 100 | 35.06 | 5610 |
| 05 | SBR-IN-05-1-TRPH | 429 | <5X | 100 | 36.05 | 15465 | SBR-EFF-05-1-TRPH | 114 | <5X | 100 | 44.59 | 5083 |
| 06 | SBR-IN-06-1-TRPH | 50 | ND | 100 | 36.06 | 1803 | SBR-EFF-06-1-TRPH | 50 | ND | 100 | 25.86 | 1293 |
| 07 | SBR-IN-07-1-TRPH | 50 | ND | 100 | 36.05 | 1802 | SBR-EFF-07-1-TRPH | 50 | ND | 100 | 36.13 | 1807 |
| 08 | SBR-IN-08-1-TRPH | 50 | ND | 100 | 35.94 | 1797 | SBR-EFF-08-1-TRPH | 50 | ND | 100 | 34.87 | 1743 |
| 08 | SBR-IN-08-5-TRPH | 50 | ND | 100 | 35.94 | | SBR-EFF-08-5-TRPH | 50 | ND | 100 | 34.87 | |
| 09 | SBR-IN-09-1-TRPH | 228 | <5X | 100 | 35.99 | 8206 | SBR-EFF-09-1-TRPH | 418 | <5X | 100 | 35.22 | 14722 |
| 10 | SBR-IN-10-1-TRPH | 214 | <5X | 100 | 35.35 | 7565 | SBR-EFF-10-1-TRPH | 530 | | 100 | 34.82 | 18455 |
| 11 | SBR-IN-11-1-TRPH | 690 | | 100 | 34.93 | 24102 | SBR-EFF-11-1-TRPH | 700 | | 100 | 34.17 | 23919 |
| 12 | SBR-IN-12-1-TRPH | 670 | | 100 | 34.12 | 22860 | SBR-EFF-12-1-TRPH | 690 | | 100 | 38.66 | 26675 |
| 13 | SBR-IN-13-1-TRPH | 412 | <5X | 100 | 34.59 | 14251 | SBR-EFF-13-1-TRPH | 650 | | 100 | 31.49 | 20469 |
| 14 | SBR-IN-14-1-TRPH | 660 | | 100 | 34.31 | 22645 | SBR-EFF-14-1-TRPH | 840 | | 100 | 35.26 | 29618 |
| TOTAL (first 9 days) | | | | | | 34244 | (last 9 days) | | | | | 138701 |
| AVERAGE | | 261 | | | | | | 343 | | | | |
| STANDARD DEVIATION | | 250 | | | | | | 287 | | | | |
| REL. STD. DEV. (%) | | 96 | | | | | | 84 | | | | |
| VARIANCE | | 62728 | | | | | | 82565 | | | | |
| MASS CLOSURE (%) – first 9 days compared to last 9 days | | | | | | | | | | | | -305.04 |

+ NOT INCLUDED IN STATISTICAL CALCULATIONS BECAUSE REPORTED VALUE WAS OUTLIER

QUALIFIERS: <5X – less than 5 times the practical quantitation limit (PQL)
ND – Not Detected

FILENAME: TB4-59

TABLE 4-64. SBR CHEMICAL OXYGEN DEMAND

| INFLUENT | | | EFFLUENT | |
|---|---|---|---|---|
| DAY | SAMPLE ID | COD (mg/L) | SAMPLE ID | COD (mg/L) |
| 01 | SBR-IN-01-1-COD | 2300 | SBR-EFF-01-1-COD | 1800 |
| 02 | SBR-IN-02-1-COD | 1500 | SBR-EFF-02-1-COD | 1600 |
| 03 | SBR-IN-03-1-COD | 990 | SBR-EFF-03-1-COD | 1300 |
| 04 | SBR-IN-04-1-COD | 1100 | SBR-EFF-04-1-COD | 1700 |
| 05 | SBR-IN-05-1-COD | 1100 | SBR-EFF-05-1-COD | 1500 |
| 06 | SBR-IN-06-1-COD | 3300 | SBR-EFF-06-1-COD | 2800 |
| 07 | SBR-IN-07-1-COD | 2000 | SBR-EFF-07-1-COD | 2000 |
| 08 | SBR-IN-08-1-COD | 1900 | SBR-EFF-08-1-COD | 2400 |
| 08 | SBR-IN-08-5-COD | 2700 | SBR-EFF-08-5-COD | 2300 |
| 09 | SBR-IN-09-1-COD | 2100 | SBR-EFF-09-1-COD | 2700 |
| 10 | SBR-IN-10-1-COD | 2300 | SBR-EFF-10-1-COD | 1800 |
| 11 | SBR-IN-11-1-COD | 4200 | SBR-EFF-11-1-COD | 2700 |
| 12 | SBR-IN-12-1-COD | 2400 | SBR-EFF-12-1-COD | 1700 |
| 13 | SBR-IN-13-1-COD | 1600 | SBR-EFF-13-1-COD | 2000 |
| 14 | SBR-IN-14-1-COD | 2200 | SBR-EFF-14-1-COD | 2500 |
| AVERAGE | | 2113 | | 2053 |
| STANDARD DEVIATION | | 828 | | 465 |
| RELATIVE STD. DEV. (%) | | 39 | | 23 |
| VARIANCE | | 685,000 | | 216,000 |

FILENAME: TBL4-58

Total Residue or Total Solids -- Table 4-65 presents the influent and effluent solids results. Total sample weight was calculated by multiplying the sample volume (50 ml) by the appropriate density. The density was assumed to be the average of the two daily measurements shown in Table 4-45. Each 50 ml sample was separated into two components by filtration; a filtercake, which was predominantly but not completely solid, and a filtrate, which was predominantly but not completely water. The laboratory measured the weights and percent solids of the filtercake. For the filtrate, solids were measured as total suspended solids (TSS), which amounted to <0.5% of the solid in all samples. These measurements were then used to calculate the total percent solids in the original sample as follows:

Filtercake

- solid wt. = (filtercake wt) x (solid mass fraction)

Filtrate

- filtrate wt = sample wt - filtercake wt.
- solid wt = (TSS) x (filtrate wt)/(1gm/cc x 1000cc/L x 1000mg/gm)

Total Sample

- solids wt = filtercake solid wt + filtrate solid wt
- % solids = (solids wt/total sample wt) x 100

The total solids mass balance is shown in Table 4-66. For the influent stream, the solids weight percent for day 1 was an outlier point. This could have been due to the fact that influent was stored in a tank that allowed solids to settle to the bottom resulting in an unrepresentative first sample. Data for day 5 were not available so the average value calculated for the other days was used. All statistical parameters were determined without using these two days. The solids mass was calculated by multiplying the mass by the corresponding solids weight fraction.

The average influent solids weight percent is 10.5 with a RSD of 28% and the average effluent solids weight percent is 10.8 with a RSD of 30%. This would indicate that the solids content was unaffected by the SBR, which is not surprising since the solids are inert clay and silt. The large day-to-day variations in the solids weight percent for both influent and effluent do, however, indicate that there is poor mixing in the storage tank. The solids mass closure between influent and effluent was good with a discrepancy of about 6%.

Total Organic Halides (TOX) -- Table 4-67 shows the influent and effluent TOX concentrations. The TOX concentrations, particularly for the effluent, show a great deal of variability, based on the limited data. Although there appears to be a reduction in TOX across the SBR in terms of both concentration and mass, it is difficult to say what the level of reduction is, given the wide variability of the effluent concentrations, questions about detection limits and matrix spike recoveries, and operating difficulties in the first five days of testing and the resultant lack of data. No conclusions can be drawn.

TABLE 4-65. TOTAL SOLIDS

| Sample-ID | TOTAL SAMPLE (50 ml) | | FILTERCAKE | | | FILTRATE | | | TOTAL SAMPLE | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Density (gm/ml) | Wgt. (gm) | Wgt. (gm) | % Solids | Solid Wgt. (gm) | Wgt. (gm) | TSS (mg/L) | Solid Wgt. (gm) | Solids Wgt. (gm) | % Solids |
| SBR-IN-01-1 | 1.050 | 52.5 | 30.40 | 50 | 15.20 | 22.10 | 155 | 0.0034 | 15.20 | 28.96 |
| -02-1 | 1.022 | 51.1 | 10.66 | 48 | 5.12 | 40.44 | 102 | 0.0041 | 5.12 | 10.02 |
| -03-1 | 1.018 | 50.9 | 14.49 | 46 | 6.67 | 36.39 | 78 | 0.0028 | 6.67 | 13.11 |
| -04-1 | 1.020 | 51.0 | 9.85 | 53 | 5.22 | 41.15 | * | ---- | ---- | 10.24 + |
| -06-1 | 1.014 | 50.7 | 6.78 | 46 | 3.12 | 43.92 | 103 | 0.0045 | 3.12 | 6.16 |
| -07-1 | 1.020 | 51.0 | 7.38 | 50 | 3.69 | 43.60 | 100 | 0.0044 | 3.69 | 7.25 |
| -08-1 | 1.019 | 50.9 | 15.40 | 46 | 7.08 | 35.53 | 136 | 0.0048 | 7.09 | 13.92 |
| -08-5 | 1.019 | 50.9 | 15.30 | 48 | 7.34 | 35.63 | 127 | 0.0045 | 7.35 | 14.43 |
| -09-1 | 1.022 | 51.1 | 14.70 | 48 | 7.06 | 36.38 | * | ---- | ---- | 13.81 + |
| -10-1 | 1.019 | 50.9 | 6.57 | 44 | 2.89 | 44.38 | * | ---- | ---- | 5.67 + |
| -11-1 | 1.014 | 50.7 | 11.40 | 42 | 4.79 | 39.30 | * | ---- | ---- | 9.44 + |
| -12-1 | 1.020 | 51.0 | 9.20 | 51 | 4.69 | 41.78 | * | ---- | ---- | 9.20 + |
| -13-1 | 1.033 | 51.7 | 13.10 | 53 | 6.94 | 38.55 | * | ---- | ---- | 13.44 + |
| -14-1 | 1.039 | 51.9 | 9.70 | 50 | 4.85 | 42.25 | * | ---- | ---- | 9.34 + |
| SBR-EFF-01-1 | 1.024 | 51.2 | 24.90 | 33 | 8.22 | 26.28 | 678 | 0.0178 | 8.23 | 16.09 |
| -02-1 | 1.039 | 51.9 | 11.47 | 50 | 5.74 | 40.46 | 575 | 0.0233 | 5.76 | 11.09 |
| -03-1 | 1.031 | 51.6 | 8.40 | 51 | 4.28 | 43.15 | 571 | 0.0246 | 4.31 | 8.36 |
| -04-1 | 0.999 | 49.9 | 13.67 | 47 | 6.42 | 36.26 | 470 | 0.0170 | 6.44 | 12.90 |
| -05-1 | 1.039 | 51.9 | 6.78 | 44 | 2.98 | 45.17 | 420 | 0.0190 | 3.00 | 5.78 |
| -06-1 | 1.029 | 51.4 | 16.90 | 45 | 7.60 | 34.53 | 434 | 0.0150 | 7.62 | 14.82 |
| -07-1 | 1.026 | 51.3 | 6.46 | 43 | 2.78 | 44.82 | 413 | 0.0185 | 2.80 | 5.45 |
| -08-1 | 1.028 | 51.4 | 10.90 | 53 | 5.78 | 40.50 | 479 | 0.0194 | 5.80 | 11.28 |
| -08-5 | 1.028 | 51.4 | 10.00 | 39 | 3.90 | 41.40 | 482 | 0.0200 | 3.92 | 7.63 |
| -09-1 | 1.029 | 51.4 | 15.10 | 47 | 7.10 | 36.32 | * | ---- | ---- | 13.80 + |
| -10-1 | 1.025 | 51.2 | 14.80 | 44 | 6.51 | 36.43 | * | ---- | ---- | 12.71 + |
| -11-1 | 1.024 | 51.2 | 12.00 | 52 | 6.24 | 39.20 | 400 | 0.0157 | 6.26 | 12.22 |
| -12-1 | 1.022 | 51.1 | 12.47 | 51 | 6.36 | 38.61 | 420 | 0.0162 | 6.38 | 12.48 |
| -13-1 | 1.025 | 51.2 | 11.00 | 49 | 5.39 | 40.23 | * | ---- | ---- | 10.52 + |
| -14-1 | 1.023 | 51.1 | 7.56 | 46 | 3.48 | 43.57 | * | ---- | ---- | 6.80 + |

FILENAME: TBL4-61

* No TSS data for these samples.

\+ % solids does not include TSS from the filtrate.

TABLE 4-66. SBR TOTAL SOLIDS BALANCES

| INFLUENT | | | | EFFLUENT | | | |
|---|---|---|---|---|---|---|---|
| SAMPLE ID | SAMPLE MASS (gm) | SOLIDS WEIGHT % | SOLIDS MASS (gm) | SAMPLE ID | SAMPLE MASS (gm) | SOLIDS WEIGHT % | SOLIDS MASS (gm) |
| SBR-IN-01-1-TSS | 31730 | 29.0 | 9189 | SBR-EFF-01-1-TSS | 32050 | 16.1 | 5157 |
| SBR-IN-02-1-TSS | 34200 | 10.0 | 3427 | SBR-EFF-02-1-TSS | 34850 | 11.1 | 3865 |
| SBR-IN-03-1-TSS | 34710 | 13.1 | 4550 | SBR-EFF-03-1-TSS | 34690 | 8.4 | 2900 |
| SBR-IN-04-1-TSS | 36650 | 10.2 | 3753 | SBR-EFF-04-1-TSS | 35060 | 12.9 | 4523 |
| SBR-IN-05-1-TSS | 36710 | 10.5 | 3840 + | SBR-EFF-05-1-TSS | 46310 | 5.8 | 2677 |
| SBR-IN-06-1-TSS | 36570 | 6.2 | 2253 * | SBR-EFF-06-1-TSS | 26590 | 14.8 | 3941 |
| SBR-IN-07-1-TSS | 36770 | 7.3 | 2666 | SBR-EFF-07-1-TSS | 37100 | 5.5 | 2022 |
| SBR-IN-08-1-TSS | 36590 | 13.9 | 5187 | SBR-EFF-08-1-TSS | 35830 | 11.3 | 3388 * |
| SBR-IN-08-5-TSS | 36590 | 14.4 | | SBR-EFF-08-5-TSS | 35830 | 7.6 | |
| SBR-IN-09-1-TSS | 36710 | 13.8 | 5070 | SBR-EFF-09-1-TSS | 36200 | 13.8 | 4996 |
| SBR-IN-10-1-TSS | 35990 | 5.7 | 2041 | SBR-EFF-10-1-TSS | 35670 | 12.7 | 4534 |
| SBR-IN-11-1-TSS | 35540 | 9.4 | 3355 | SBR-EFF-11-1-TSS | 34950 | 12.2 | 4271 |
| SBR-IN-12-1-TSS | 35030 | 9.2 | 3223 | SBR-EFF-12-1-TSS | 39550 | 12.5 | 4936 |
| SBR-IN-13-1-TSS | 35690 | 13.4 | 4797 | SBR-EFF-13-1-TSS | 32240 | 10.5 | 3392 |
| SBR-IN-14-1-TSS | 35590 | 9.3 | 3324 | SBR-EFF-14-1-TSS | 36160 | 6.8 | 2459 |
| TOTAL OF 14 DAYS | | | 56673 | | | | 53058 |
| AVERAGE | | 10.46 | | | | 10.80 | |
| STD. DEV. | | 2.92 | | | | 3.19 | |
| REL. STD. DEV. % | | 27.89 | | | | 29.51 | |
| VARIANCE | | 8.52 | | | | 10.15 | |
| MASS CLOSURE % | | | | | | | 6.38 |

FILENAME: TBL4-62

* Average of split sample measurement

+ Solids Weight % assumed to be average value

TABLE 4-67. TOTAL ORGANIC HALIDES MATERIAL BALANCE

| INFLUENT | | | | | | | EFFLUENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | SAMPLE ID | TOX (mg/L) | QUALIFIER | DETECTION LIMIT (mg/L) | VOLUME (L) | TOX MASS (mg) | SAMPLE ID | TOX (mg/L) | QUALIFIER | DETECTION LIMIT (mg/L) | SAMPLE VOLUME (L) | TOX MASS (mg) |
| 04 | SBR-IN-04-1-TOX | 0.97000 | | 0.1000 | 36.01 | 34.93 | | | | | | |
| 05 | SBR-IN-05-1-TOX | 1.29999 | Q | 0.1000 | 36.05 | 46.86 | | | | | | |
| 06 | SBR-IN-06-1-TOX | 1.20000 | | 0.1000 | 36.06 | 43.27 | | | | | | |
| 08 | | | | | | | SBR-EFF-08-1-TOX | 0.74000 | | 0.1000 | 34.87 | 25.80 |
| 08 | | | | | | | SBR-EFF-08-5-TOX | 0.11999 | <5X | 0.1000 | 34.87 | 4.18 * |
| 10 | | | | | | | SBR-EFF-10-1-TOX | 1.39999 | | 0.0100 | 34.82 | 48.75 |
| 12 | | | | | | | SBR-EFF-12-1-TOX | 0.40000 | | 0.0100 | 38.66 | 15.46 |
| TOTAL | | | | | 108.12 | 125.07 | | | | | 108.35 | 90.0154 |
| AVERAGE | | 1.16 | | | | | | 0.66 | | | | |
| STANDARD DEVIATION | | 0.14 | | | | | | 0.48 | | | | |
| RELATIVE STD. DEV. (%) | | 11.94 | | | | 28.03 | | 71.85 | | | | |
| VARIANCE | | 0.02 | | | | | | 0.23 | | | | |
| MASS CLOSURE (%) | | | | | | | | | | | | 28 |

FILENAME: TBL4-63

FOOTNOTE: Q denotes spike recoveries outside of control limits
* Not accounted for in mass balance
< 5X = less than 5 times practical quantitation limit (PQL)

Chloride Ion (Cl) -- Table 4-68 presents the influent and effluent chloride ion data. A significant increase in both concentration and mass is observed. As with the TOX data, the variations in influent concentration are far lower (~3%) than for effluent concentration (~43%). The average chloride mass almost doubles between influent and effluent. Comparing the chloride results with the total organic halide results, it can be seen that a reduction in TOX corresponds to an increase in chloride. Although this is not a 1:1 correspondence, it could be presumed that it is the result of converting relatively toxic chlorophenols to the more benign inorganic form. What is not clear is the exact magnitude of the conversion. This dechlorination process is verified by the reduction in penta concentration discussed earlier, but it cannot be concluded from the chloride data that total mineralization of penta takes place.

Other Metals -- Concentrations of other metals in the SBR effluent are shown in Table 4-69. Non-detected values for particular metals were not included in the calculation of statistical parameters. No cadmium or selenium was detected. The average barium concentration was 18 ppm with a deviation of 11%; as noted in earlier sections, the source of the barium is unknown. The average lead concentration was 10 ppm with a deviation of 11%. The average mercury concentration was 8.6 ppb with a deviation of 63%. The average silver concentration was 180 ppb with a deviation of 23%.

Since concentrations of these other metals in the influent stream were not measured, it is impossible to state whether the SBR affected them in any way.

EP Toxicity -- From the limited amount of EP Toxicity data presented in Table 4-70 it appears that very little cadmium, lead, mercury, selenium or silver leached from the effluent stream. The average arsenic concentration was 1.2 mg/L with a deviation of 32%. Barium showed the largest variation with a deviation of 60% and an average concentration of 117 ug/L. Average chromium concentration was 30 ug/L with a deviation of 10%. Average copper concentration was 79 ug/L with a deviation of 9%.

#### 4.4.4.3 System Parameters

No penta or PAHs were detected on the carbon from the adsorption canister. This would indicate that very little, if any, of the target semi-volatile organic compounds escape from the unit as vapor.

pH measurements over the course of the test are shown in Table 4-71 and Figure 4-38. The first readings on day four are suspect. The influent pH was less than that for the effluent pH; presumably due to the addition of caustic. (The reasonably stable pH suggests that pH fluctuations is not a major cause of variations in penta concentrations.)

Power usage on a day-by-day basis is shown in Table 4-72 and plotted in Figure 4-39. Over the 14 day test period, 16.7 kw-hr of electricity was consumed. On this basis, the average daily consumption is approximately 1.2 kw-hr. And, since ~490 liters (130 gallons) or 499 Kg (1100 lb) of slurry were treated during this period, the electrical usage can be estimated to be 0.034kwh/L (0.13 kwh/gal).

TABLE 4-68. CHLORIDE MATERIAL BALANCE

| INFLUENT | | | | | EFFLUENT | | | |
|---|---|---|---|---|---|---|---|---|
| DAY | SAMPLE ID | Cl (mg/L) | VOLUME (L) | Cl MASS (mg) | SAMPLE ID | Cl (mg/L) | VOLUME (L) | Cl MASS (mg) |
| 04 | SBR-IN-04-1-CL | 79.2 | 36.01 | 2851.99 | | | | |
| 05 | SBR-IN-05-1-CL | 83.9 | 36.05 | 3024.60 | | | | |
| 06 | SBR-IN-06-1-CL | 77.5 | 36.06 | 2794.65 | | | | |
| 08 | | | | | SBR-EFF-08-1-CL | 79.4 | 34.87 | 2749.50 * |
| 08 | | | | | SBR-EFF-08-5-CL | 78.3 | 34.87 | |
| 10 | | | | | SBR-EFF-10-1-CL | 203.0 | 34.82 | 7068.46 |
| 12 | | | | | SBR-EFF-12-1-CL | 194.0 | 38.66 | 7500.04 |
| TOTAL | | | | 8671.24 | | | | 17317.99 |
| AVERAGE | | 80.20 | | | | 138.68 | | |
| STANDARD DEVIATION | | 2.71 | | | | 59.91 | | |
| REL. STD. DEV. (%) | | 3.38 | | | | 43.20 | | |
| VARIANCE | | 7.33 | | | | 3589.31 | | |
| MASS CLOSURE (%) | | | | | | | | -99.72 |

FILENAME: TBL4-64
FOOTNOTE: * Mass calculation based on average of split sample

TABLE 4-69. EFFLUENT METALS CONCENTRATION
(ug/l)

| Sample-ID<br>Test Day-Time Period | Time Sampled | Acurex ID | Barium | Cadmium | Lead | Mercury | Selenium | Silver |
|---|---|---|---|---|---|---|---|---|
| SBR-EFF-01-1-MET | 1015 | 8910121 | 12000 | < 50 | 6080 | 5.7 | < 30 | < 100 |
| SBR-EFF-02-1-MET | 1100 | 8910137 | 18000 | < 50 | 9350 | 8.3 | < 30 | 170 |
| SBR-EFF-03-1-MET | 1100 | 8910144 | 20700 | < 50 | 11100 | 5.0 | < 30 | 180 |
| SBR-EFF-04-1-MET | 1100 | 8910147 | 19000 | < 50 | 10500 | < 0.2 | < 30 | 250 |
| SBR-EFF-05-1-MET | 1045 | 8910147 | 19300 | < 50 | 10500 | 7.5 | < 30 | 130 |
| SBR-EFF-06-1-MET | 1100 | 8910157 | 19100 | < 50 | 10400 | 9.4 | < 30 | 210 |
| SBR-EFF-07-1-MET | 1115 | 8910161 | 19000 | < 50 | 10400 | < 2.0 | < 30 | 140 |
| SBR-EFF-08-1-MET | 1100 | 8910176 | 20000 | < 50 | 10600 | 8.6 | < 30 | < 100 |
| SBR-EQB-08-5-MET | 1100 | 8910176 | 17800 | < 50 | 10200 | 7.9 | < 30 | < 100 |
| SBR-EFF-09-1-MET | N/A | 8910180 | 18300 | < 50 | 10000 | 5.3 | < 30 | < 100 |
| SBR-EFF-10-1-MET | 1100 | 8910183 | 18400 | < 50 | 9930 | 8.6 | < 30 | < 100 |
| SBR-EFF-11-1-MET | 1105 | 8910187 | 17300 | < 50 | 10100 | 18.2 | < 30 | < 100 |
| SBR-EFF-12-1-MET | 1115 | 8910187 | 16600 | < 50 | 9720 | 3.1 | < 30 | < 100 |
| SBR-EFF-13-1-MET | 1100 | 8910195 | 16400 | < 50 | 9310 | 22.2 | < 30 | < 100 |
| SBR-EFF-14-1-MET | 1100 | 8911001 | 17600 | < 50 | 9510 | 2.4 | < 30 | < 100 |
| AVERAGE | | | 17967 | | 9847 | 8.6 | | 0 |
| STD. DEV. | | | 1960 | | 1116 | 5.4 | | 0 |
| REL. STD. DEV. (%) | | | 11 | | 11 | 62.7 | | -- |
| VARIANCE | | | 3840000 | | 1245000 | 29.3 | | 0 |

N/A = Not Available

FILENAME: TBL4-65

TABLE 4-70. EFFLUENT E P TOXICITY ANALYSIS
(ug/l)

| Sample-ID Test Day-Time Period | Time Sampled | Acurex ID | Arsenic | Barium | Cadmium | Chromium | Copper | Lead | Mercury | Selenium | Silver |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SBR-EFF-08-1-MET | 1100 | 8910176 | 929 | 215 | < 5.0 | 29.5 | 71 | < 50 | 0.23 | < 200 | < 10 |
| SBR-EFF-10-1-MET | 1100 | 8910183 | 930 | 82 | < 5.0 | 27.2 | 88.8 | < 50 | < 0.2 | < 200 | < 10 |
| SBR-EFF-12-1-MET | 1115 | 8910187 | 1760 | 54.9 | < 5.0 | 34.2 | 76.8 | < 50 | < 0.2 | < 200 | < 10 |
| AVERAGE | | | 1206 | 117 | | 30 | 79 | | | | |
| STD. DEV. | | | 392 | 70 | | 3 | 7 | | | | |
| REL. STD. DEV. (%) | | | 32 | 60 | | 10 | 9 | | | | |
| VARIANCE | | | 153000 | 4900 | | 8 | 55 | | | | |

FILENAME: TBL4-66

TABLE 4-71. SBR pH DATA

| DAY | DATE | TIME | pH INFLUENT | EFFLUENT | ELAPSED TIME (hr) |
|---|---|---|---|---|---|
| 01 | 10/17/89 | 14:08 | 6.67 | 7.27 | 0.00 |
| | 10/18/89 | 02:10 | 6.15 | 7.10 | 12.03 |
| 02 | 10/18/89 | 16:00 | 6.31 | 7.08 | 25.87 |
| | 10/19/89 | 01:45 | 6.19 | 7.29 | 35.62 |
| 03 | 10/19/89 | 13:59 | 6.39 | 7.19 | 47.85 |
| | 10/20/89 | 01:37 | 6.01 | 7.19 | 59.48 |
| 04 | 10/20/89 | 14:04 * | 6.91 * | 7.99 | 71.93 |
| | 10/21/89 | 01:30 | 6.33 | 6.97 | 83.37 |
| 05 | 10/21/89 | 13:55 | 6.26 | 6.96 | 95.78 |
| | 10/22/89 | 01:55 | 6.06 | 6.73 | 107.78 |
| 06 | 10/22/89 | 13:54 | 6.54 | 7.37 | 119.77 |
| | 10/23/89 | 02:00 | 6.12 | 6.99 | 131.87 |
| 07 | 10/23/89 | 13:52 | 6.35 | 6.96 | 143.73 |
| | 10/24/89 | 01:47 | 5.82 | 6.85 | 155.65 |
| 08 | 10/24/89 | 13:59 | 6.34 | 6.91 | 167.85 |
| | 10/25/89 | 01:45 | 5.90 | 6.91 | 179.62 |
| 09 | 10/25/89 | 13:48 | 6.30 | 6.96 | 191.67 |
| | 10/26/89 | 01:35 | 6.13 | 6.94 | 203.45 |
| 10 | 10/26/89 | 13:50 | 6.31 | 7.06 | 215.70 |
| | 10/27/89 | 01:15 | 5.86 | 6.86 | 227.12 |
| 11 | 10/27/89 | 14:16 | 6.23 | 6.74 | 240.13 |
| | 10/28/89 | 01:30 | 5.95 | 6.54 | 251.37 |
| 12 | 10/28/89 | 14:09 | 6.17 | 6.60 | 264.02 |
| | 10/29/89 | 01:20 | 6.29 | 6.58 | 275.20 |
| 13 | 10/29/89 | 13:58 | 6.21 | 6.42 | 287.83 |
| | 10/30/89 | 01:20 | 6.38 | 6.88 | 299.20 |
| 14 | 10/30/89 | 14:08 | 6.44 | 6.43 | 312.00 |
| | 10/31/89 | 01:10 | 6.53 | 6.37 | 323.03 |
| 15 | 10/31/89 | 09:47 | 6.45 | 6.23 | 331.65 |

* suspect reading

FILENAME: TBL4-67

Figure 4-38. Slurry Bio-Reactor

Influent & Effluent pH Data

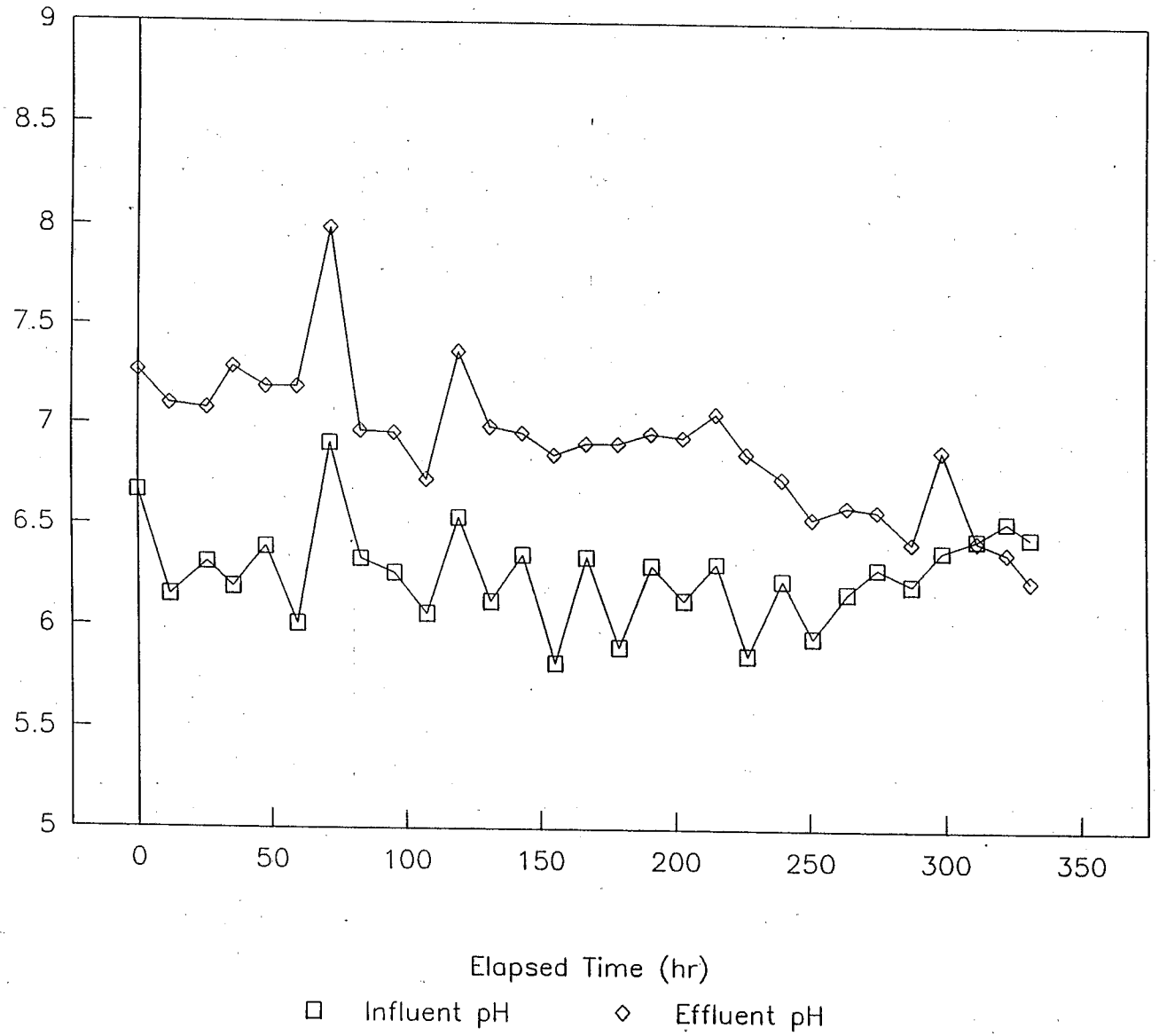


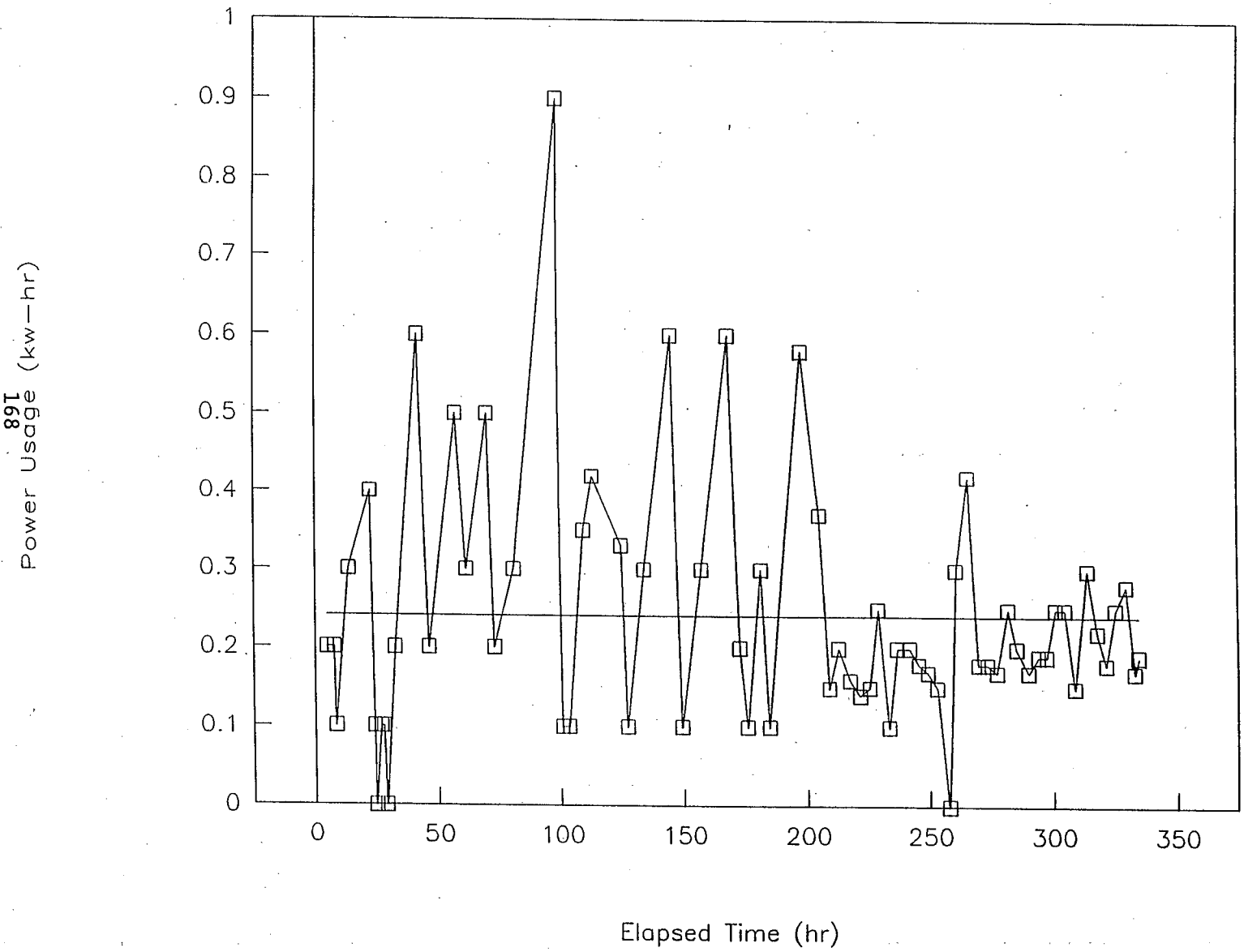
TABLE 4–72. SBR POWER USAGE

| DAY | DATE | TIME | ELAPSED TIME (HR) | METER READING (KW–HR) | POWER USAGE (KW–HR) |
|---|---|---|---|---|---|
| 1 | 10/17 | 12:28 | 0.0 | 59.3 | |
| 1 | 10/17 | 17:10 | 4.7 | 59.5 | 0.2 |
| 1 | 10/17 | 20:10 | 7.7 | 59.7 | 0.2 |
| 1 | 10/17 | 21:00 | 8.5 | 59.8 | 0.1 |
| 1 | 10/18 | 02:06 | 13.6 | 60.1 | 0.3 |
| 2 | 10/18 | 10:40 | 22.2 | 60.5 | 0.4 |
| 2 | 10/18 | 12:20 | 23.9 | 60.6 | 0.1 |
| 2 | 10/18 | 12:50 | 24.4 | 60.6 | 0 |
| 2 | 10/18 | 14:55 | 26.5 | 60.7 | 0.1 |
| 2 | 10/18 | 16:03 | 27.6 | 60.8 | 0.1 |
| 2 | 10/18 | 17:00 | 28.5 | 60.8 | 0 |
| 2 | 10/18 | 20:45 | 32.3 | 61.0 | 0.2 |
| 2 | 10/19 | 08:00 | 41.5 | 61.6 | 0.6 |
| 3 | 10/19 | 10:40 | 46.2 | 61.8 | 0.2 |
| 3 | 10/19 | 21:35 | 57.1 | 62.3 | 0.5 |
| 3 | 10/20 | 01:47 | 61.3 | 62.6 | 0.3 |
| 4 | 10/20 | 10:22 | 69.9 | 63.1 | 0.5 |
| 4 | 10/20 | 13:10 | 72.7 | 63.3 | 0.2 |
| 4 | 10/20 | 21:00 | 80.5 | 63.6 | 0.3 |
| 5 | 10/21 | 14:12 | 97.7 | 64.5 | 0.9 |
| 5 | 10/21 | 17:00 | 100.5 | 64.6 | 0.1 |
| 5 | 10/21 | 19:50 | 103.4 | 64.7 | 0.1 |
| 5 | 10/22 | 01:55 | 109.4 | 65.05 | 0.35 |
| 5 | 10/22 | 05:30 | 113.0 | 65.47 | 0.42 |
| 6 | 10/22 | 17:10 | 124.7 | 65.8 | 0.33 |
| 6 | 10/22 | 19:35 | 127.1 | 65.9 | 0.1 |
| 6 | 10/23 | 02:28 | 134.0 | 66.2 | 0.3 |
| 7 | 10/23 | 13:35 | 145.1 | 66.8 | 0.6 |
| 7 | 10/23 | 17:37 | 149.1 | 66.9 | 0.1 |
| 7 | 10/24 | 01:48 | 157.3 | 67.2 | 0.3 |
| 8 | 10/24 | 12:45 | 168.3 | 67.8 | 0.6 |
| 8 | 10/24 | 17:15 | 172.8 | 68.0 | 0.2 |
| 8 | 10/24 | 20:15 | 175.8 | 68.1 | 0.1 |
| 8 | 10/25 | 01:49 | 181.3 | 68.4 | 0.3 |
| 8 | 10/25 | 05:14 | 184.8 | 68.5 | 0.1 |
| 9 | 10/25 | 18:25 | 197.9 | 69.08 | 0.58 |
| 9 | 10/26 | 01:35 | 205.1 | 69.45 | 0.37 |
| 9 | 10/26 | 05:20 | 208.9 | 69.6 | 0.15 |
| 9 | 10/26 | 09:15 | 212.8 | 69.8 | 0.2 |
| 10 | 10/26 | 13:53 | 217.4 | 69.96 | 0.16 |
| 10 | 10/26 | 18:00 | 221.5 | 70.1 | 0.14 |
| 10 | 10/26 | 21:39 | 225.2 | 70.25 | 0.15 |
| 10 | 10/27 | 01:15 | 228.8 | 70.5 | 0.25 |
| 10 | 10/27 | 05:43 | 233.2 | 70.6 | 0.1 |
| 10 | 10/27 | 09:06 | 236.6 | 70.8 | 0.2 |
| 11 | 10/27 | 14:16 | 241.8 | 71.0 | 0.2 |
| 11 | 10/27 | 18:03 | 245.6 | 71.2 | 0.18 |
| 11 | 10/27 | 21:38 | 249.2 | 71.4 | 0.17 |
| 11 | 10/28 | 01:30 | 253.0 | 71.5 | 0.15 |
| 11 | 10/28 | 06:15 | 257.8 | 71.5 | 0 |
| 11 | 10/28 | 09:14 | 260.8 | 71.8 | 0.3 |
| 12 | 10/28 | 14:09 | 265.7 | 72.2 | 0.42 |
| 12 | 10/28 | 18:07 | 269.7 | 72.4 | 0.18 |
| 12 | 10/28 | 21:40 | 273.2 | 72.6 | 0.18 |
| 12 | 10/29 | 01:25 | 277.0 | 72.8 | 0.17 |
| 12 | 10/29 | 06:02 | 281.6 | 73.0 | 0.25 |
| 12 | 10/29 | 09:30 | 285.0 | 73.2 | 0.2 |
| 13 | 10/29 | 14:07 | 289.7 | 73.37 | 0.17 |
| 13 | 10/29 | 18:04 | 293.6 | 73.56 | 0.19 |
| 13 | 10/29 | 21:34 | 297.1 | 73.75 | 0.19 |
| 13 | 10/30 | 01:17 | 300.8 | 74.0 | 0.25 |
| 13 | 10/30 | 05:00 | 304.5 | 74.25 | 0.25 |
| 13 | 10/30 | 09:00 | 308.5 | 74.4 | 0.15 |
| 14 | 10/30 | 14:13 | 313.7 | 74.7 | 0.3 |
| 14 | 10/30 | 18:00 | 317.5 | 74.92 | 0.22 |
| 14 | 10/30 | 21:32 | 321.1 | 75.1 | 0.18 |
| 14 | 10/31 | 01:18 | 324.8 | 75.35 | 0.25 |
| 14 | 10/31 | 05:37 | 329.1 | 75.63 | 0.28 |
| 14 | 10/31 | 09:00 | 332.5 | 75.8 | 0.17 |
| 15 | 10/31 | 10:45 | 334.3 | 75.99 | 0.19 |
| TOTAL | | | | | 16.69 |
| AVERAGE | | | | | 0.24 |
| STD. DEV. | | | | | 0.16 |
| REL. STD. DEV. (%) | | | | | 65.43 |
| VAR. | | | | | 0.03 |

FILENAME: TBL4–68

Figure 4-39. Slurry Bio-Reactor

POWER USAGE



### 4.4.5 Dioxins/Furans

#### 4.4.5.1 Introduction

Removal of chlorinated dioxins and furans was not a stated objective of the vendor; rather the data were collected to guide the project team in determining disposal for waste materials from the project. To determine the contaminant reductions during the demonstration, the distribution of various CDD and CDF congeners was measured for each technology. An operational term, 'Total CDD/CDFs', is used to describe the sum of all CDD (tetra-, penta-, hexa-, hepta-, octa-) and CDF (tetra-, penta-, hexa-, hepta-, octa-) congeners and isomers. This term, Total CDD/CDFs, is then used to estimate the changes between input and output streams for each technology.

#### 4.4.5.2 CDDs/CDFs in Soil Washer Streams

The presence of CDDs in the Feed Soil and all output streams from the BioTrol Soil Washing System was measured, including:

2,3,7,8-tetrachloro-dibenzo(p)dioxin (2,3,7,8-TCDD),
other tetrachlorodibenzodioxin congeners (TCDD),
pentachlorodibenzodioxins(PeCDD),
hexachlorodibenzodioxins (HxCDD),
heptachlorodibenzodioxins (HeCDD),
octachlorodibenzodioxins (OCDD),

and the following CDFs:

tetrachlorodibenzofurans(TCDF),
pentachlorodibenzofurans (PeCDF),
hexachlorodibenzofurans (HxCDF),
heptachlorodibenzofurans (HpCDF)
and octachlorodibenzofurans (OCDF)

The number of samples analyzed are limited, usually to two for a particular stream, and the average results for the Total CDD/CDFs in all streams in the Low Penta SW test and the High Penta SW test, respectively, are summarized in Table 4-73 and 4-74 . Concentrations of individual congeners in each stream from each test are also presented in Table 4-75.

Comparison of various stream profiles for CDD/CDF distribution reveals the following:

(a) OCDD is the most significant among the CDD/CDF congeners present in all the stream samples, accounting for about 61-66% of the Total CDD/CDFs, followed by HpCDD (13.2 - 13.5%), HpCDF (8.4 - 11.8%), OCDF (7.8 - 11.6%), HxCDF (2.1 -4.7%), and HxCDD (0.8 - 1.0%). TCDD, PeCDD, TcCDF and the congener usually of primary interest, 2,3,7,8-TCDD were not detected.

(b) A comparison of the concentrations of individual CDDs and CDFs in various process stream samples reveals that the pattern of the

TABLE 4-73. TOTAL CDD/CDF DATA - LOW SOIL TEST *

| Soil Washer Streams | Rate kg/hr. | Input or Output/kg Feed Soil | Total CDD/CDF Conc. (ppm) | Total CDD/CDF Mass/Fraction (mg/kg) | Percent of Output |
|---|---|---|---|---|---|
| INPUT STREAMS | | | | | |
| Feed Soil | 220.0 | 1.00 | 1.370 | 1.37 | 100 |
| Municipal Water | 1200.0 | 5.45 | 0.000 | | |
| ATS effluent | N/A | -- | - | | |
| Thickener Stream | 180.0 | 0.82 | 0.000 | | |
| TOTAL | 1600.0 | 7.27 | | 1.37 | 100 |
| OUTPUT STREAMS | | | | | |
| Washed Soil | 260.0 | 1.18 | 0.110 | 0.13 | 12.0 |
| Fine Oversize | 13.0 | 0.06 | 1.820 | 0.11 | 9.9 |
| Coarse Oversize | 32.0 | 0.15 | 1.040 | 0.15 | 14.0 |
| Fine Particle Cake | 48.0 | 0.22 | 3.130 | 0.68 | 63.1 |
| Combined Dewater.Eff | 1148.0 | 5.22 | 0.002 | 0.01 | 1.0 |
| TOTAL | 1501.0 | 6.82 | | 1.08 | 100.0 |

file: tabl469

* CDD/CDF average concentrations represents mean of at least duplicate samples.

TABLE 4-74. TOTAL CDD/CDF DATA - HIGH SOIL TEST *

| Soil Washer Streams | Rate kg/hr. | Input or Output/kg Feed Soil | Total CDD/CDF Conc. (ppm) | Total CDD/CDF Mass/Fraction (mg/kg) | Percent of Output |
|---|---|---|---|---|---|
| INPUT STREAMS | | | | | |
| Feed Soil | 160.0 | 1.00 | 2.508 | 2.51 | 100 |
| Municipal Water | 36.0 | 0.23 | 0.000 | | |
| ATS effluent | 660.0 | 4.13 | 0.000 | | |
| Thickener Stream | 120.0 | 0.75 | 0.000 | | |
| TOTAL | 976.0 | 6.10 | 2.508 | 2.51 | 100 |
| OUTPUT STREAMS | | | | | |
| Washed Soil | 210.0 | 1.31 | 0.078 | 0.10 | 4.8 |
| Fine Oversize | 9.1 | 0.06 | 1.235 | 0.07 | 3.3 |
| Coarse Oversize | 28.0 | 0.18 | 2.319 | 0.41 | 18.9 |
| Fine Particle Cake | 36.0 | 0.23 | 6.818 | 1.53 | 71.4 |
| Combined Dewater.Eff | 720.0 | 4.50 | 0.008 | 0.04 | 1.7 |
| TOTAL | 1003.1 | 6.27 | | 2.15 | 100.0 |

file: tabl470

* CDD/CDF average concentrations represents mean of at least duplicate samples.

TABLE 4-75. SOIL WASHER: CDD/CDF CONCENTRATIONS IN ALL STREAMS

| Soil Test | CDD/CDF Congeners Concentration @ | | | | | | | | | | | TOTAL CDD | TOTAL CDF | TOTAL CDD/CDF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2378-TCDD | TCDD | PeCDD | HxCDD | HpCDD | OCDD | TCDF | PeCDF | HxCDF | HpCDF | OCDF | | | |
| I. Low Soil Test | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | |
| Feed Soil # | 0.00 | 0.00 | 0.00 | 13.00 | 180.00 | 830.00 | 0.00 | 3.20 | 59.00 | 160.00 | 120.00 | 1023.00 | 342.20 | 1365.20 |
| % of total input | 0.0 | 0.0 | 0.0 | 1.0 | 13.2 | 60.8 | 0.0 | 0.2 | 4.3 | 11.7 | 8.8 | 74.9 | 25.1 | 100.0 |
| Municipal Water $ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Flocculant $ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ATW $ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Output | | | | | | | | | | | | | | |
| Washed Soil ** | 0.00 | 0.00 | 0.00 | 1.00 | 11.60 | 71.02 | 0.01 | 0.24 | 4.62 | 11.60 | 8.80 | 83.62 | 25.27 | 108.89 |
| Coarse Oversize | 0.00 | 0.00 | 0.00 | 7.60 | 125.00 | 670.00 | 0.03 | 3.55 | 39.50 | 115.50 | 82.00 | 802.60 | 240.58 | 1043.18 |
| Fine Oversize | 0.00 | 0.00 | 0.00 | 14.00 | 230.00 | 1150.00 | 0.04 | 6.70 | 74.00 | 190.00 | 160.00 | 1394.00 | 430.74 | 1824.74 |
| Fine Particle Cake | 0.00 | 0.00 | 0.00 | 27.30 | 455.00 | 1850.00 | 0.19 | 2.05 | 167.50 | 405.00 | 222.50 | 2332.30 | 797.24 | 3129.54 |
| CDE | 0.00 | 0.00 | 0.00 | 0.01 | 0.19 | 1.16 | 0.00 | 0.00 | 0.08 | 0.19 | 0.16 | 1.36 | 0.42 | 1.78 |
| % of Total CDD/CDFs output | 0.0 | 0.0 | 0.0 | 0.8 | 13.5 | 61.3 | 0.0 | 0.2 | 4.7 | 11.8 | 7.8 | 75.5 | 24.5 | 100.0 |
| II. High Soil Test | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | |
| Feed Soil # | 0.00 | 0.00 | 0.00 | 21.00 | 330.00 | 1600.00 | 0.00 | 2.10 | 53.00 | 212.00 | 290.00 | 1951.00 | 557.10 | 2508.10 |
| % of Total CDD/CDFs input | 0.0 | 0.0 | 0.0 | 0.8 | 13.2 | 63.8 | 0.0 | 0.1 | 2.1 | 8.5 | 11.6 | 77.8 | 22.2 | 100.0 |
| Municipal Water $ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Flocculant $ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ATW $ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Output | | | | | | | | | | | | | | |
| Washed Soil * | 0.00 | 0.00 | 0.00 | 0.47 | 10.00 | 53.44 | 0.00 | 0.05 | 1.67 | 6.00 | 6.43 | 63.91 | 14.15 | 78.06 |
| Coarse Oversize | 0.00 | 0.00 | 0.00 | 18.00 | 315.00 | 1505.00 | 0.00 | 2.35 | 45.50 | 193.00 | 240.50 | 1838.00 | 481.35 | 2319.35 |
| Fine Oversize | 0.00 | 0.00 | 0.00 | 6.60 | 171.50 | 805.00 | 0.00 | 2.05 | 32.50 | 106.50 | 110.50 | 983.10 | 251.55 | 1234.65 |
| Fine Particle Cake | 0.00 | 0.00 | 0.00 | 53.50 | 900.00 | 4500.00 | 0.00 | 9.55 | 140.00 | 575.00 | 640.00 | 5453.50 | 1364.55 | 6818.05 |
| CDE | 0.00 | 0.00 | 0.00 | 0.05 | 1.05 | 5.50 | 0.00 | 0.01 | 0.18 | 0.66 | 0.73 | 6.60 | 1.57 | 8.17 |
| % of Total CDD/CDFs output | 0.0 | 0.0 | 0.0 | 0.8 | 13.4 | 65.7 | 0.0 | 0.1 | 2.1 | 8.4 | 9.5 | 79.8 | 20.2 | 100.0 |

@ Unless otherwise stated, all concentrations in ug/L or ug/kg and represent duplicates.
# Data from a single sample
* Mean of seven samples
** Mean of five samples
$ Not analyzed for CDD/CDFs

relative proportions of all CDD and CDF congeners tested is uniform for all streams and, largely, for both the Low Penta and the High Penta tests. Although of different magnitude, the patterns for the various CDDs and CDFs are superimposable where measureable.

(c) Since the congener pattern for all input and output streams is superimposable for all 11 CDDs and CDFs, estimation of process efficiency on the basis of the major dioxin congener, OCDD, may adequately describe process characteristics and performance.

Low Penta SW Test -- The levels and pattern of distribution of CDDs and CDFs in the Low Penta SW process streams indicate that OCDD is the most significant of the CDD/CDFs in the soil samples and represents about 61% of the total CDD/CDF mass in all the process streams. This is followed by HpCDD (13.5%), HpCDF (11.8%), OCDF (7.8%), HxCDF (4.7%), HxCDD (0.8%), and PeCDF (0.2%). The distribution of all isomers is presented in Table 4-75.

The Total CDD/CDF concentration in the Washed Soil (0.11 mg/kg) represents 8% of the Total CDD/CDF concentration in the Feed Soil (1.365 mg/kg), equivalent to a % Removal Efficiency of 92% of the input CDD/CDFs. While the Total CDD/CDFs in the Washed Soil represents only 12% of the cumulative Total CDD/CDF mass in all outputs (Table 4-73), it must be recognized that there is a significant discrepancy between the calculated input mass (1.37 mg/kg of Feed Soil) and the combined output mass (1.08 mg) of Total CDD/CDFs (mass balance: 79%).

The Coarse Oversize fraction, which contributes approximately 2.1% of the total output mass, contains 13.9% of the Total CDD/CDF output mass in the Low Penta SW test. The Fine Oversize (8.7% of the output mass) contains about 10.2% of the Total CDD/CDF mass. The Fine Particle Cake, containing the highest concentration of Total CDD/CDFs in 3.2% of the output mass, also contributes the largest portion to the output mass of Total CDD/CDFs, 63%.

The Combined Dewatering Effluent, CDE, is the largest of the stream outputs, with 76% of the total output mass, but accounts for only 0.9% of the Total CDD/CDF output mass. This is probably attributable to the low solubility of the CDD/CDFs in water and, in fact, the amount of dioxins/ furans present may only be due to suspended solids in the water.

High Penta SW Test -- In the High Penta SW test, an exceptionally high 97% Removal Efficiency is calculated based on the Total CDD/CDF concentration in the Feed Soil (2.508 mg/kg) and that in the Washed Soil (0.078 mg/kg). The Washed Soil, representing 20.9% of the total output mass, contains only 4.6% of the output mass of Total CDD/CDFs and 4% of the input CDD/CDFs mass (Table 4-74). In this test, the Total CDD/CDF mass input and output are in closer agreement, with a mass balance of 86%.

The Coarse Oversize, (2.9% of output mass) contains 19% of the Total CDD/CDF output mass and the Fine Oversize (0.96% of output mass) contains 3.2% of the output mass of Total CDD/CDF. Combined they account for 19.1% of the Total CDD/CDF input mass. The Fine Particle Cake, representing only 3.7% of the output

mass, contains 71% of the output Total CDD/CDF mass and 61% of the input Total CDD/CDF mass.

As expected, the CDE process stream contained insignificant concentrations of CDD/CDFs (total: 8.2 µg/L). Although CDE mass is 72% of the total output mass per period, this stream contains only 1.9% of the Total CDD/CDF output mass and 1.6% of the input mass from the Feed Soil. As noted above, this probably is due to the hydrophobic character of CDD/CDFs and CDD/CDFs in the CDE process stream also may be due to suspended particulates with adsorbed CDDs/CDFs. Although the CDE masses are comparable in both the High Penta (72%) and Low Penta (76%) tests, the CDE from the High Penta test contained almost twice as much, 1.8%, of the Total CDD/CDF output; however, this observation is based on very limited data and may be due to suspended solids carryover, differences in the soil composition, CDD/CDF sources, analytical precision, etc.

Materials/Mass/Balance -- Mass balances were carried out for both the Low Penta and the High Penta SW tests. Based on averaged input and output flows, it is evident from the totals in Tables 4-73 and 4-74 that satisfactory material balances (6% and -3% for the Low and High Penta tests, respectively) were achieved. For Total CDDs/CDFs, the mass balances were 79% and 86%, respectively. However, the BATS effluent (ATS) was not analyzed for CDD/CDFs. This could significantly affect the calculations for the High Penta SW test since BATS Effluent represents 81% of the liquid input and 68% of the total input mass.

#### 4.4.5.3 CDD/CDFs in the BioTrol Aqueous Treatment System

CDD/CDF concentrations in the BATS effluent samples are as shown in Table 4-76. The mean daily Total CDD/CDF concentration in the BATS effluent stream was 194.8 µg/L (range: 12-503 µg/L). The effluent Total CDD levels ranged from 12-403 µg/L (mean: 140 µg/L). Among the CDD congeners, only HxCDD and OCDD were detected in the effluent streams; OCDD was detected in all the effluent samples from BATS. Likewise, the mean daily effluent output of CDF congeners was 54.84 µg/L (range: 0-99.8 µg/L). Penta-, hexa-, hepta-, and octachlorodibenzofurans were detected in at least one effluent sample from the BATS. Note that 2,3,7,8-TCDD, TCDD, PeCDD, HpCDD, and TCDF, and PeCDF were not detected in any of the BATS effluent samples. In the absence of CDD/CDF congeners concentrations for the influent to the BATS reactor, no conclusions concerning removal by the system are possible.

#### 4.4.5.4 CDD/CDFs in the Slurry Bio-Reactor

The results of the eight analyses for 6 CDD and 5 CDF congeners in the SBR effluent streams over the course of the fourteen day test with the fine particle slurry from the High Penta SW test are as shown in Table 4-77. The average Total CDD/CDF concentration in the SBR effluent samples was 6,300 µg/kg (range: 0.0-9,272 µg/kg). CDD congeners with a mean total output of 4,960 µg/kg (range 0.0-7,260 µg/kg) constitute 78 percent of the total CDD/CDF load in the

TABLE 4-76. AQUEOUS TREATMENT SYSTEM: CDD/CDF CONCENTRATIONS IN THE EFFLUENT STREAMS

| CDD/CDF | CDD/CDF Concentrations * | | | | | Mean Daily Output |
|---|---|---|---|---|---|---|
| | eff-01 | eff-03 | eff-05 | eff-07 | eff-09 | |
| 2378-TCDD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TCDD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PeCDD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| HpCDD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| HxCDD | 0.00 | 27.00 | 0.00 | 63.00 | 0.00 | 18.00 |
| OCDD | 37.00 | 180.00 | 41.00 | 340.00 | 12.00 | 122.00 |
| TCDF | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PeCDF | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| HxCDF | 0.00 | 8.90 | 0.00 | 6.80 | 0.00 | 3.14 |
| HpCDF | 0.00 | 31.00 | 0.00 | 42.00 | 0.00 | 14.60 |
| OCDF | 0.00 | 25.00 | 0.00 | 51.00 | 0.00 | 15.20 |
| TOTAL CDD | 37.00 | 207.00 | 41.00 | 403.00 | 12.00 | 140.00 |
| TOTAL CDF | 0.00 | 64.90 | 0.00 | 99.80 | 0.00 | 32.90 |
| TOTAL CDD/CDF | 37.00 | 271.90 | 41.00 | 502.80 | 12.00 | 172.90 |

file: 4-71

* Unless otherwise stated, CDD/CDF concentrations data were obtained from a single sample
All data is in ng/L

TABLE 4-77. SLURRY BIO-REACTOR: CDD/CDF CONCENTRATIONS IN THE EFFLUENT STREAMS

| CDD/CDF | CDD/CDF Concentrations * | | | | | | | | Average Output (8 days) |
|---|---|---|---|---|---|---|---|---|---|
| | eff-01 | eff-03 | eff-05 | eff-07 | eff-09# | eff-11 | eff-13 | eff-14# | |
| 2378-TCDD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| TCDD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| PeCDD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| HxCDD | 41.0 | 41.0 | 50.0 | 46.0 | 47.0 | 52.0 | 60.0 | 0.0 | 42.13 |
| HpCDD | 780.0 | 780.0 | 940.0 | 900.0 | 900.0 | 940.0 | 1100.0 | 0.0 | 792.50 |
| OCDD | 4200.0 | 4200.0 | 3900.0 | 5000.0 | 4710.0 | 4900.0 | 6100.0 | 0.0 | 4126.25 |
| TCDF | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| PeCDF | 10.0 | 11.0 | 17.0 | 20.0 | 16.5 | 24.0 | 32.0 | 0.0 | 16.31 |
| HxCDF | 150.0 | 150.0 | 170.0 | 200.0 | 160.0 | 190.0 | 250.0 | 0.0 | 158.75 |
| HpCDF | 580.0 | 570.0 | 650.0 | 760.0 | 715.0 | 770.0 | 1000.0 | 0.0 | 630.63 |
| OCDF | 520.0 | 540.0 | 580.0 | 640.0 | 670.0 | 600.0 | 730.0 | 0.0 | 535.00 |
| TOTAL CDD | 5021.0 | 5021.0 | 4890.0 | 5946.0 | 5657.0 | 5892.0 | 7260.0 | 0.0 | 4960.88 |
| TOTAL CDF | 1260.0 | 1271.0 | 1417.0 | 1620.0 | 1561.5 | 1584.0 | 2012.0 | 0.0 | 1340.69 |
| TOTAL CDD/CDF | 6281.0 | 6292.0 | 6307.0 | 7566.0 | 7218.5 | 7476.0 | 9272.0 | 0.0 | 6301.56 |

* Unless otherwise stated, CDD/CDF concentration data were obtained from a single sample. Concentrations of CDD/CDF are in ug/kg.

# Duplicate samples analyzed

SBR output streams. Hexa-, hepta-, and octa- CDDs were detected in all effluent samples except day 14. Among the CDF congeners penta-, hexa-, hepta-, and octa-CDFs were detected in all the effluent samples. The mean total CDF output was 1,340 µg/kg (range: 0.0-2,012 µg/kg) and represents 22 percent of the Total CDD/CDF load in the SBR-treated slurry. Data are not available on the slurry of fines fed to the SBR and the data for the Fine Particle Cake obtained after dewatering are not a good representation of the slurry; therefore, removal cannot be evaluated.

## 4.5 FACTORS AFFECTING THE DEMONSTRATION

### 4.5.1 Unit Operating Problems - Soil Washer

Several relatively minor and fully expected difficulties were encountered during the demonstration. These are described below both to document how the problems were addressed to minimize impact on the study and to alert the developer and potential users to changes in equipment or its design that may be called for. The major operating problem encountered during the SW tests was in the transfer of soil from the feed hopper to the conveyor belt. The feed hopper was a new feed system used for the first time during this demonstration. Because of a higher than expected moisture content, the soil was coating the screws in the feed hopper, making it necessary to increase in the auger rate from 10% to 80% to maintain the same feed rate. This higher auger rate is subject to greater variability. Attempts were made to aerate the feed soils to decrease their moisture content and to modify the feed hopper with a vibrating device and inclined, wooden walls to help keep the augers clear. This enabled the demonstration tests to be completed. However, in a commercial scale system a different means of delivering soil to the conveyor belt will be needed.

Minor problems that were encountered included blown fuses, a broken shim on an attrition machine, the overall centrifuge operation, and failure of various pumps. In these cases the equipment was either repaired or replaced. In a commercial facility, back-up equipment or parts would need to be readily available to avoid shut-down of the system or two Soil Washers might need to be run in a parallel configuration to allow for the shut-down of a unit for routine maintenance.

### 4.5.2 BioTrol Aqueous Treatment System Problems

Operational problems encountered during the demonstration included a leaking influent pump, a leaking recycle line, worn bearings in the influent pump, and the overheating of the BATS reactor. Repairs of the pumps and recycle line were relatively minor but did require the cut-off of feed to the system for short periods of time. Having replacement pumps on hand would avoid any loss of feed for more than a few minutes. The overheating of the BATS reactor occurred due to a major decrease in flow rate (from 3 gpm down to 0.5 gpm) when the bearings in the influent pump had worn out. This decrease in flow rate should have been accompanied by a corresponding decrease in the thermostat setting on the heater but subsequent overheating occurred when the thermostat was not adjusted. The result was deactivation of the biomass due to extreme temperatures in the BATS reactor. This occurred on the 10th day of the High Penta

demonstration test and sufficient data had already been collected so that the test was considered concluded at that time.

### 4.5.3 Slurry Bio-Reactor Problems

Operating problems encountered during the demonstration of the SBR included clogging of the lines connecting the cells of the reactor, rupture of the line in the effluent pump, blown circuit breakers, and ambient temperatures below freezing. A rubber mallet was used to loosen material caught between reactor cells; in a larger system this is not expected to be a problem. The line in the effluent pump was replaced following each occurrence of a rupture. The tripped circuit breaker was reset as soon as it was discovered, which was immediately upon occurrence. The feed system was dependent upon a timer which diverted flow 6 seconds out of each minute. If power were cut off for any extended period of time, this timer would need to be reprogrammed. Although the reactor cells are equipped with automatic temperature controls, the feed tank was not. A propane heater was used on extremely cold nights inside the temporary structure to keep the feed from freezing.

## 4.6 POTENTIAL OVERALL SYSTEM PERFORMANCE

If all units were fully integrated in size, operation of the SW system would return Washed Soil to the site, segregate Coarse and Fine Oversize, and biologically treat the Combined Dewatering Effluent in the BATS and the Fine Particle Cake (as slurry) in the SBR. Using the normalized 1.0 kg of Feed Soil, and making the following assumptions, the overall fate of soil and penta then can be estimated.

Assumptions

Solid mass balance is good
Penta mass balance is good
BATS operates at 90% removal efficiency
SBR operates at 90% removal efficiency
Effluent from BATS is recycled
Treated slurry from SBR is returned to site

With a soil such as that used in the Low Penta test, 1.0 kg of Feed Soil, containing 175 mg of penta (based on the output penta mass rather than the lower input mass), produces the following:

- 0.06 kg Fine Oversize (containing 5.8 mg penta) and 0.14 kg Coarse Oversize (containing 23.8 mg penta) to be disposed of off-site, probably by incineration;
- 1.18 kg of Washed Soil (16.5 mg penta) that it is presumed could be returned to the site;
- 0.22 kg of Fine Particle Cake (59.4 mg penta) that would be treated in the Slurry Bio-Reactor to remove 90% of the penta, leaving only 5.9 mg. It is assumed that the slurry then could be returned to the site.

- 5.0 kg of Combined Dewatering Effluent (70 mg penta) that would be treated in the BATS to achieve a 90% penta reduction to 7.0 mg; the treated effluent would be recycled.

  With a soil such as that used in the High Penta test, 1.0 kg of Feed Soil, containing 1066 mg of penta (output penta mass rather than the lower input mass), produces the following:

- 0.06 kg Fine Oversize (54 mg penta) and 0.18 kg Coarse Oversize (252 mg penta) to be disposed of off-site;

- 1.31 kg of Washed Soil (114 mg penta). At a concentration of 87 mg/kg, it is questionable whether this material would be suitable for return to the site without further treatment, even though ~90% of the penta has been removed.;

- 0.22 kg of Fine Particle Cake (1300 mg penta) that would be treated in the Slurry Bio-Reactor to remove 90% of the penta, leaving 130 mg. The treated slurry, then containing about 590 mg/kg, probably could not be returned to the site without further treatment. If SBR treatment achieved 99% at steady state, the resulting slurry would have only 13 mg and, consequently, about 59 ppm.

- 4.5 kg of Combined Dewatering Effluent (360 mg penta) that would be treated in the BATS to achieve a 90% penta reduction to 36.0 mg; the treated effluent would then be recycled.

Thus, the overall effect is a segregation of the penta (and PAH) contamination into three relatively small streams: the Coarse and Fine Oversize, which are disposed of off-site, and the Fine Particle Cake, which is treated in the SBR, to degrade approximately 90% of its contaminants. The Combined Dewatering Effluent is treated in the BATS for reuse or is polished further with carbon before discharge. The bulk of the material returned to the site, the Washed Soil (and the treated Fine Particle slurry), would contain only a small portion of the original contamination. As noted earlier, the decision concerning return of material to the site remains a regulatory one.

It also may be feasible to recycle at least a portion of the CDE as input water to the Soil Washer without treatment. Even though the CDE contributes 35-40% of the penta mass in the two tests, its contribution to any of the solid output streams would not be large. Since penta concentration would, presumably, be limited to its solubility (~80 mg/L), its contribution would be limited to 80 mg for each kilogram of water used. Experiments would be needed to evaluate the buildup of penta, PAHs, and metals.

## SECTION 5

## ECONOMIC ANALYSIS

### 5.1 INTRODUCTION

A pilot-scale demonstration test, such as the one conducted here, is very often done before a commercial-scale remediation is attempted to prove the applicability of the technology for a specific waste matrix and/or a specific set of waste characteristics at a particular site. An "order-of-magnitude" cost estimate for a hypothetical demonstration test at a "generic" site is presented here based on costs incurred under the SITE program, on costs estimated by BioTrol, and data obtained from other sources. Breakdown of these costs into the same 12 categories that are used in the Applications Analysis has been attempted for comparison purposes.

### 5.2 BASIS OF ECONOMIC ANALYSIS

The demonstration system used by BioTrol to quote costs consists of a 225-450 kg/hr (0.25-0.50 ton/hr) Soil Washer followed by a 19 L/min (5 gpm) BioTrol Aqueous Treatment System and a 0.02 L/min (0.006 gpm) Slurry Bio-reactor. It was not possible for BioTrol to break down costs further according to the three different technologies tested because of the generic nature of this analysis. This does not mean to imply, however, that all three technologies must be used together. Any one of the three technologies supplied by BioTrol may be used alone or in conjunction with other processes that may or may not be supplied by BioTrol for a particular application. No attempt has been made here to consider the costs of such system configurations.

Table 5-1 shows the breakdown into the 12 cost categories used in the Applications Analysis. Feed soil preparation such as excavation, debris removal, blending etc. are not included. BioTrol's costs also include overhead and profit. Site preparation, and permitting and regulatory requirements combined are estimated to be $125,000. Based on experience with the SITE program, permitting and regulatory requirements are minimal. Hence the majority of this cost is associated with site preparation including shipping/freight, mobile crane service, labor, travel and per diem, and installation of utilities. It should be noted that this is a gross figure and includes many unknowns such as distance to the site, the contaminants, required process modifications, and number of pre-mobilization site visits and meetings with the client and/or regulatory agencies. This figure, $125,000, was half of the average cost proposed by BioTrol, $150,000-250,000, for mobilization and demobilization. It was felt that the upper limit of this range was more realistic due to the inclusion of the SBR in

the total clean-up system. The other half of this average figure is included in item 12, demobilization, and is dependent on decontamination requirements.

**TABLE 5-1."ORDER-OF-MAGNITUDE" COST ESTIMATE FOR A HYPOTHETICAL DEMONSTRATION TEST AT A "GENERIC" SITE**

| Cost Category | Technology | | Cost | |
|---|---|---|---|---|
| | SW | BATS | SBR | Total |
| 1 Site Preparation | | | | $125,000 |
| 2 Permitting and Regulatory Req. | | | | |
| 3 Capital Equipment | | | | |
| 4 Start-Up | | | | |
| 5 Labor | | $45,000/wk | $25,000/wk | |
| 6 Consumables and Supplies | | | | |
| 7 Utilities | | | | |
| 8 Effluent Treatment & Disposal | | | | |
| 9 Residuals/Waste Shipping & Handling | | | | $117,000 |
| 10 Analytical Services | | $6000/day | $1200/day | $7200/day |
| 11 Maintenance & Modification | included in items 3-7 above | | | |
| 12 Demobilization | | | | $125,000 |

BioTrol estimated the cost of operation for the SW/BATS combination at $35,000-45,000 per week. For a two week demonstration test, the upper end of this range was used and included capital equipment (including rental of earth moving equipment, office trailer with toilet, and decontamination trailer), start-up, labor (including travel and per diem), consumables and supplies (including flocculent, nutrients, and protective clothing/equipment), utilities, maintenance and modification.

For the SBR, BioTrol estimates operating costs at $15,000 - $25,000 per week. Since the flow through the SBR is much lower than that in the SW/BATS combination, it would have to be operated for a longer period of time to treat the effluent from the 2 week SW/BATS demonstration test. For a 4-6 week SBR demonstration test preceded by a 5-10 day acclimation period, costs would again be in the upper portion of this range. Operating costs for the acclimation period have been included in the site preparation costs. It was assumed that SBR operation would begin after the Soil Washer was operated for 1 week.

Based on the SITE demonstration, effluent treatment and disposal, and residuals/waste shipping and handling were estimated at $117,000. It should be noted that the Fine and Coarse Oversize woody debris from the Soil Washer was not incinerated during the demonstration test, but was drummed for off-site landfill. This was less costly than incineration because of the smaller volume of waste generated.

Analytical services was the cost category that was the most difficult to estimate. Costs from the demonstration test would not be indicative of a

commercial application because of the extensive analytical QA/QC requirements of the SITE program. Analytical costs are highly dependent upon project scope, i.e., the contaminants, the number of bulk soil samples to test with the process, the length of the test, and decontamination requirements imposed by the regulating agency. During operation, the Soil Washer may generate 6-12 composite samples per day. The BioTrol Aqueous Treatment System and Slurry Bio-Reactor may each generate fewer samples per day. The total number of samples and the parameters to be analyzed will determine the analytical costs. A cost-saving step would be to choose one or two "indicator" compounds and do the analyses only on these compounds during preliminary testing. Once the process is optimized, analyses for all contaminants of interest can be done. For purposes of this discussion, it was assumed that a "generic" group of analyses of a sample would cost $600 including the containers, shipping and handling, QA/QC analyses, and reporting. It was further assumed that 8 samples per day would be taken from the Soil Washer and 2 samples per day (influent/effluent) for the BioTrol Aqueous Treatment System and 2 samples per day (influent/effluent) for the Slurry Bio-Reactor. The SW/BATS would generate 10 samples/day for 2 weeks while the SBR would generate 2 samples/day for 4-6 weeks. Thus the total analytical costs are estimated to be:

| | | |
|---|---|---|
| SW/BATS | 10 samples/day x 15 days x $600/sample = | $ 90,000 |
| SBR | 2 samples/day x 40 days x $600/sample = | $ 48,000 |
| | | $138,000 |

The total cost for operating a typical pilot-scale demonstration test would then be broken down this way:

| | Percent of Total Cost | Total Costs |
|---|---|---|
| Mobilization | $125,000 | 16.8 |
| SW/BATS Operation ($45,000/wk x 2 wk) | 90,000 | 12.1 |
| SBR Operation ($25,000/wk x 6 wk) | 150,000 | 20.1 |
| Residual shipping/handling and disposal | 117,000 | 15.7 |
| Analytical | 138,000 | 18.5 |
| Demobilization | 125,000 | |
| TOTAL | $745,000 | 100 |

The largest cost item is equipment operation (32%), followed by analytical (18.5%) and mobilization/demobilization (16.8%) expenses. This would indicate that waste site characteristics and test objectives play an important role in determining costs. It is important, therefore, to define these parameters at the beginning of the test. Capital cost for equipment lease has been included in the operating cost of the testing program. Assuming continuous operation of the SW at 0.375 ton/hour during 2 weeks, a total of 114,500 kg (126 tons) of soil would be treated. The unit cost would then be about $6.50/kg or $6,000/ton.

The reader must be cautioned that this is for a pilot-scale operation and does not relate to a full-scale installation. The cost per ton of soil treated for full scale, commercial operation would drop dramatically from $6.50/kg to $0.19/kg ($168/ton). There are two major reasons for this. First, it was assumed that the full-scale equipment was purchased outright and then amortized over a

10-year life cycle period rather than leased. Under these circumstances, capital equipment costs were about $40,000/month, excluding labor, as opposed to $280,000/month, including labor, to lease the pilot-scale unit. This represents a seven-fold difference. Second, the amount of soil treated increased two orders of magnitude, from 115 metric tons (126 short tons) to 34,724 metric tons (38,273 short tons). The processing rate also increased proportionally, by two orders of magnitude, but the associated equipment costs did not. This occurs because it requires larger volumes which only cost incrementally more, rather than orders of magnitude more. Hence, the cost in terms of $/ton goes down.

The full-scale treatment system would consist of an 18.2 metric ton/hour (20 short ton/hour) Soil Washer with a cost of $170/metric ton ($154/short ton) or $257/m$^3$ ($197/yd$^3$) of soil treated; three 378.5 L/min (100 gpm) BATS units connected in parallel with a cost of $1.73/metric ton ($1.57/short ton) of soil or $0.44/1000 L ($1.65/1000 gal) of water treated; and an 87 L/min (23 gpm) SBR with a cost of $2.92/metric ton ($2.65/short ton) of soil trated or $9.22/1000 L ($34.39/1000 gal) of slurry treated. These costs are based on the treatment of 34,724 metric tons (38,273 short tons) or 22,938 m$^3$ (30,000 yd$^3$) of contaminated soil. In addition, the cost for incineration of the fine and coarse oversize material has been included in the cost of the soil washer; it contributes about 80% to that cost figure or 75% to the overall cost.

## SECTION 6

## QUALITY ASSURANCE/QUALITY CONTROL

### 6.1 INTRODUCTION

The demonstration test of the Biotrol soil washing process, designed for removing pentachlorophenol (penta) and polynuclear aromatic hydro-carbons (PAHs) from contaminated soil, was conducted in accordance with a detailed Quality Assurance Project Plan (QAPjP). The QAPjP contained numerical specifications for data quality in terms of precision, accuracy, completeness, and also required the use of standardized methods to insure data comparability and representativeness. The intent of this section is to review these objectives and report on the quality of the data in terms of these defined objectives.

In order to satisfy data quality objectives, as defined above, a sophisticated quality control process was implemented. This process focussed on controlling measurement error associated with both sampling and field activities through the use of laboratory spikes (surrogate and matrix), replicate sampling, field and laboratory blanks, and strict adherence to QA/QC requirements of the methods specified in the QAPjP. When appropriate, these methods were modified to satisfy field requirements.

In addition to these controls, frequent laboratory and field audits were conducted by EPA and by contractor QA personnel. As discussed in the following summary, several corrective action procedures were required as a result of these audits. Numerous obstacles were noted throughout the course of this project which potentially or directly affected the quality of the collected data. In some instances special studies were instituted to learn the effect of these difficulties upon data quality. In addition, detailed analyses have been conducted to determine the data quality impact of potentially negative results obtained from data quality indicators. The presented discussions are intended to inform the reader of potential impacts upon data quality, and the evaluation in Section 6.2, summarizes what were considered to be the more critical data quality problems. This section also explains how these problems were reconciled during the course of the project.

Certain key measurements were used to determine process removal efficiencies as they related to project objectives for penta and PAHs. These included penta and PAH analyses in feed soil and washed soil for the soil washer, influent and effluent streams for the slurry bioreactor, and influent and effluent streams for the aqueous treatment system. These were all defined as critical measurements for this demonstration. In addition, for purposes of obtaining a mass balance and to learn the fate of other contaminants and their effect upon removal efficiencies of penta and PAHs, other analyses were defined as secondary critical

measurements. These included copper (Cu), chromium (Cr), and arsenic (As) analyses, polychlorinated dibenzo-dioxins/ polychlorinated dibenzo-furans (PCDDs/PCDFs), total residue, and measurements of penta and PAHs in matrices other than those defined above. All other measurements were considered non-critical and results of these analyses were not directly related to project objectives.

## 6.2 CONCLUSIONS AND LIMITATIONS OF DATA

As presented in this entire QA/QC section as well as in the main portion of the report, several occurrences during the course of this demonstration could have a significant impact on the quality of the data. These problems are discussed in detail in the remainder of section 6 and are summarized below. In review, the most significant problems were; 1) holding times for extractions and analyses which exceeded QAPjP and analytical specifications, 2) the lack of MS/MSD data for all soil and slurry matrices, 3) the lack of sufficient data to properly characterize the efficiency of the slurry bioreactor, and 4) the inability to reconcile a mass balance between influent and effluent contaminants. Because of the negative potential of each of these problems to affect data quality, significant efforts have been made to determine the seriousness of each of these occurrences and the resulting impact upon data generated during the course of the project.

Holding times were examined in detail by conducting a separate holding time study to determine if a holding time bias existed. Because holding times were exceeded for a large portion of the samples, several sample replicates were re-extracted or reanalyzed and concentrations were compared to original sample analyses conducted within the specified holding time to determine if a change had occurred. In addition to the samples chosen for reanalysis, a significant number of replicate samples analyzed by the laboratory were evaluated such that one sample was analyzed within holding time and another was analyzed outside the holding time. While this often occurred only by chance and was not deliberate planning, these sample comparisons added to the information gained by the holding time studies.

In brief, holding time study results showed no detectable concentration bias for the period of time over which the study was conducted. In addition, several sample concentration comparisons of replicate samples analyzed by the laboratory also showed similar data with no significant sample bias due to holding time. Two solid matrices (fine particle cake and fine oversize) showed a possible holding time bias, however, this proved to be inconclusive. In addition, these two matrices were not critical for determining the efficiency of the process, but were used only as part of the mass balance calculation. While holding time bias cannot be completely ignored, because the number of total samples used in the study is small and not statistically significant, the study does show that this bias was not measurable within the observed sampling and analytical precision. Impact upon the quality of the final data set is therefore considered to be insignificant.

MS/MSD data are of little use for determining the extraction efficiency of pentachlorophenol in solid matrices because the concentration of penta spiked

into the matrix is often much lower than the native concentration. Usually, the spike was as much as ten times below the native penta concentration. This problem occurred because samples were not properly screened by the laboratory prior to being spiked with the compound of interest. While matrix spikes cannot be used to determine accuracy or extraction efficiency, results of surrogate spiking suggest that extractions were within QAPjP limits, and in fact, extra efforts were made by the laboratory to re-extract all samples which did not fall within surrogate spiking specifications. Results from any re-extracted samples which did not meet the specifications stated for surrogate spikes were not used for any of the data manipulations or calculations. Accuracy of the penta extraction is therefore somewhat in question, but the surrogate spike information suggests that extraction efficiency is within specification. Additional detail is included in section 6.4.

Because the micro-organisms within the slurry bioreactor were not actively degrading the penta during a portion of the demonstration, several samples taken from the SBR showed no significant change in penta concentration. Given the difficulty in determining exactly when penta degradation is occurring (and because samples could not be immediately analyzed), the problem with the SBR was not determined during the sampling period, but only after analyses were received from the laboratory. It was also obvious from these analyses that the SBR began functioning properly part-way through the demonstration. Results therefore show a trend in efficiency, but because the efficiency is rapidly climbing during the four days over which the samples were taken, a maximum or peak efficiency for the process cannot be determined. Results reported therefore show an average efficiency for these four days and also show a trend upward suggesting that the process can maintain a higher degradation.

Mass balance between influent and effluent contaminants remains somewhat unresolved. As noted in the report, it is believed that the increase in contaminant concentration in effluent samples could be due in part to increased extraction efficiency in the laboratory as a result of further particle breakdown from the scrubbing action of the treatment process.

## 6.3 PROCEDURES DEFINING DATA QUALITY

### 6.3.1 Precision

Precision is the reproducibility or degree of agreement among replicate measurements of a single parameter. Precision for a single parameter was expressed as a percentage of the difference between results of duplicate samples for a single parameter. This relative percent difference (RPD) was calculated as:

$$RPD = \frac{\text{Maximum Value - Minimum Value}}{[(\text{Maximum Value + Minimum Value})/2]} \times 100$$

For data sets greater than two points, the coefficient of variation (CV) was used to assess precision. The %CV is calculated as:

$$\%CV = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

Precision for all measurements was calculated through examination of results for laboratory matrix spike/matrix spike duplicates (MS/MSD) and other laboratory duplicate samples. Critical measurements for organic compounds also employed precision calculations for results of field replicate sample analysis to assess combined field and laboratory variability.

### 6.3.2 Accuracy

Accuracy is the agreement between a measurement value and a theoretical or known value. Accuracy can be expressed as the relative error (%RE) where:

$$\%RE = \frac{\text{Measured Value - Theoretical Value}}{\text{Theoretical Value}} \times 100$$

Accuracy for all measurements was calculated for analytical results of analytes spiked into the sample matrix. Analytical systems were also checked routinely for system accuracy through use of calibration check samples and control samples. Matrix spike recoveries were calculated using the following equation:

$$\%\text{Recovery (spike)} = \frac{C_{ss} - C_{us}}{C_{sa}} \times 100$$

Where: $C_{ss}$ = Analyte concentration in spiked sample

$C_{us}$ = Analyte concentration in unspiked sample

$C_{sa}$ = Analyte concentration added to the sample

### 6.3.3 Completeness

Measurement data completeness is a measure of the amount of valid data produced compared to the total amount of data originally planned for the project. Project measurement completeness is discussed in detail in section 6.4.

### 6.3.4 Comparability

Comparability expresses the extent with which one data set can be compared to another. This was accomplished by use of standard, accepted reference methods and adherence to protocols specified in the QAPjP and generation of quality control data. Non-standard methods used were well documented to ensure that procedures are repeatable by other investigators.

### 6.3.5 Representativeness

Representativeness refers to the degree with which analytical results accurately and precisely represent actual conditions present at locations chosen for environmental sampling. Throughout the life of this project, regular, timely reviews of analytical and quality control data were conducted to ensure that results generated could be considered representative of the actual site conditions.

## 6.4 ANALYTICAL QUALITY CONTROL

### 6.4.1 Soil Pile Analyses

Low concentration pentachlorophenol (penta) and high concentration penta soil piles were analyzed for the following parameters: Penta, polynuclear aromatic hydrocarbons (PAHs), Copper(Cu), Chromium(Cr), Arsenic(As), total residue, polychlorinated dibenzo-dioxins and polychlorinated dibenzo-furans (PCDDs/PCDFs), total metals, total organic carbon (TOC), total recoverable petroleum hydrocarbons (TRPH) and cation exchange capacity (CEC). For the low concentration soil pile, 8 separate soil sample cores were analyzed, and for the high concentration soil pile, 12 separate soil sample cores were analyzed. In addition, one composite sample was analyzed for both the high concentration and low concentration soil piles.

ACCURACY

PENTACHLOROPHENOL AND PAHs

Surrogate spike summary data for semivolatile analyses of all soil matrices (aqueous and solid) including re-extracted samples, are presented in Tables 6-1 and 6-2. As noted in these tables, soil matrices analyzed from the two soil piles (high and low penta concentration ) were generally within specified accuracy limits as determined from surrogate spike results. It should be noted that Terphenyl-d14 and 2-Fluorophenol in the aqueous matrices for the high concentration soil test, are surrogates which more often than others fell outside acceptable recovery ranges. (Specific detail regarding the surrogate spike criteria used to determine if the analyses are acceptable is presented in section 6.4.2. Data outside these specified recovery ranges were not used in the calculation of project objectives.)

Per QAPjP specifications, accuracy was also to be determined from matrix spike recoveries. Matrix spikes are intended to show the actual recovery percentage for the primary compound being analyzed in the matrix of interest. For this demonstration the critical compounds of interest were penta and PAHs. In particular, because of its high concentration in the feed soil, penta was more critical than any of the PAHs which were in relatively low concentrations. Because the concentration of penta was extremely high in the feed soil (and consequently in each of the effluent soil matrices as well as the slurry for the slurry bioreactor process), matrix spike concentrations were too low for

TABLE 6-1. ACCURACY - SURROGATE SPIKES SOIL WASHER
LOW CONCENTRATION SOIL TEST

| Analyte (Matrix) | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits |
|---|---|---|---|---|---|
| (Aqueous) | | | | | |
| NBZ | 19 | 58-105 | 35-114 | 19 | 0 |
| FBP | 19 | 58-114 | 43-116 | 19 | 0 |
| TPH | 19 | 34-121 | 33-141 | 19 | 0 |
| PHL | 19 | 18-76 | 10-94 | 19 | 0 |
| 2FP | 19 | 41-78 | 21-100 | 19 | 0 |
| TBP | 19 | 53-119 | 10-123 | 19 | 0 |
| FLT | 19 | 58-120 | 20-130 | 19 | 0 |
| (Solid) | | | | | |
| NBZ | 52 | 31-95 | 23-120 | 52 | 0 |
| FBP | 52 | 44-113 | 30-115 | 52 | 0 |
| TPH | 52 | 34-130 | 18-137 | 52 | 0 |
| PHL | 52 | 28-99 | 24-113 | 52 | 0 |
| 2FP | 52 | 40-91 | 25-121 | 52 | 0 |
| TBP | 52 | 29-100 | 19-122 | 52 | 0 |
| FLT | 52 | 0-123 | 15-140 | 51 | 1 |

NBZ Nitrobenzene-d5
FBP 2-Fluorobiphenyl
TPH Terphenyl-d14
PHL Phenol-d5
2FP 2-Fluorophenol
TBP 2,4,6-Tribromophenol
FLT Fluoranthene-d10

TABLE 6-2. ACCURACY - SURROGATE SPIKES SOIL WASHER
HIGH CONCENTRATION SOIL TEST

| Analyte (Matrix) | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits |
|---|---|---|---|---|---|
| (Aqueous) | | | | | |
| NBZ | 41 | 12-113 | 35-114 | 39 | 2 |
| FBP | 41 | 18-115 | 43-116 | 39 | 2 |
| TPH | 41 | 10-137 | 33-141 | 34 | 7 |
| PHL | 41 | 20-99 | 10-94 | 40 | 1 |
| 2FP | 41 | 4-100 | 21-100 | 43 | 8 |
| TBP | 41 | 31-119 | 10-123 | 41 | 0 |
| FLT | 41 | 29-128 | 20-130 | 41 | 0 |
| (Solid) | | | | | |
| NBZ | 101 | 0-99 | 23-120 | 100 | 1 |
| FBP | 101 | 0-120 | 30-115 | 99 | 2 |
| TPH | 101 | 14-125 | 18-137 | 100 | 1 |
| PHL | 101 | 0-91 | 24-113 | 99 | 2 |
| 2FP | 101 | 0-92 | 25-121 | 99 | 2 |
| TBP | 101 | 0-122 | 19-122 | 100 | 1 |
| FLT | 101 | 55-127 | 15-140 | 101 | 0 |

NBZ Nitrobenzene-d5
FBP 2-Fluorobiphenyl
TPH Terphenyl-d14
PHL Phenol-d5
2FP 2-Fluorophenol
TBP 2,4,6-Tribromophenol
FLT Fluoranthene-d10

accurate information to be obtained. Laboratory personnel assumed too low of a native penta concentration in aqueous and soil matrices when preparing matrix spike solutions. Spiking concentrations were based upon experience with other soil matrices and not upon actual penta concentration in the solid being analyzed for this project. Consequently, the penta matrix spike concentration was often ten times or more lower than the native compound concentration. QA personnel were made aware of this problem well after analyses were complete. In fact, during the final QA audit of data quality, laboratory personnel were still unsure about actual penta spiking concentrations. Corrective action in terms of respiking proved impractical due to the exceedingly high concentrations required, holding time considerations, and the fact that analyses had long been completed. Matrix spike information was therefore of little use in determining percent recoveries for penta, and the native concentration data presented from these MS/MSD results are used only for purposes of laboratory precision.

Table 6-3 presents the penta MS/MSD data. This table covers both soil and water matrices for the soil washer and slurry bioreactor. Generally precision is within acceptable laboratory variability. Those matrices which showed large variability were those which were also more difficult to extract due to their slurry rather than solid or aqueous nature (i.e., fine particle cake).

Matrix spike information for PAH compounds and 2,3,5,6- tetrachlorophenol in all soil washer matrices (aqueous and soil input and output streams) is presented in Table 6-4. These data indicate, that in general, extraction efficiencies were within specified limits for all spiked PAH compounds except pyrene. Because pyrene was often outside QC limits there appeared to be a matrix problem with this compound which may have an effect upon conclusions concerning removal efficiency or mass balance for pyrene and compounds similar in chemical structure and behavior.

Included in Table 6-4 are commonly used matrix spikes for SW-846 Method 8270 analysis and one added spiking compound 2,3,5,6-tetrachlorophenol (2,3,5,6-TCP). This was an additional surrogate for better determining the recovery efficiency of penta. Anticipating high levels of penta and knowing this could cause matrix spike complications 2,3,5,6-TCP was proposed during preparation of the QAPjP as an additional check of recovery efficiency for penta. As noted by the results in Table 6-4, 2,3,5,6-TCP recovery efficiency was somewhat variable as may be expected given its chemical proximity to penta and knowing from previous projects that penta can be difficult to extract from water or soil matrices. While the laboratory had no specified QC limits for recovery efficiency for 2,3,5,6-TCP (because it is not a commonly used laboratory spike) general recoveries do appear to be acceptable if compared to accepted matrix spike recovery QC limits for penta. There are some solid matrices, however, which have unacceptable recovery limits and variability. The reason this occurred is because 2,3,5,6-TCP matrix spike concentrations were based upon the samples containing no native 2,3,5,6-TCP. It was later discovered that several of the matrices did contain native 2,3,5,6-TCP, and therefore, as with the penta spikes, several of the samples were spiked at too low of a level to accurately determine recovery efficiency.

TABLE 6-3. PENTACHLOROPHENOL MS/MSD RESULTS - PRECISION

| Sample Type | MS (ug/mL) On-Column Conc | MSD (ug/mL) On-Column Conc | RPD % |
|---|---|---|---|
| WATER SAMPLES (All Treatment Processes) | | | |
| SWL-MW | 92.7 | 81.5 | 12.9 |
| SWH-MW | 67.1 | 63.7 | 5.2 |
| SWH-ATW | 199.5 | 211.7 | 5.9 |
| SBR-EQB | 93.8 | 103.2 | 9.5 |
| SBR-IN | 115 | 143 | 21.7 |
| SBR-IN | 139 | 266 | 62.7 |
| SOIL SAMPLES (All Treatment Processes) | | | |
| SPL-C | 95.8 | 91.5 | 4.6 |
| SPH | 105.1 | 118.6 | 12.1 |
| SWL-FS | 173.9 | 130.5 | 28.5 |
| SWL-FPC | 81.5 | 57.3 | 34.9 |
| SWH-FPC | 107.9 | 65.8 | 48.5 |
| SWH-FS | 84.2 | 75.3 | 11.2 |
| SWH-WS | 189.4 | 189.9 | 0.3 |

SWL - Soil Washing Low Conc
SWH - Soil Washing High Conc
SBR - Slurry Bioreactor
SPL - Soil Pile Low Conc
SPH - Soil Pile High Conc

MW - Municipal Water
ATW - ATS Recycled Water
EQB - Equipment Blank
IN - Influent
C - Composite
FS - Feed Soil
FPC - Fine Particle Cake
WS - Wash Soil

TABLE 6-4. MS/MSD DATA FOR SOIL WASHER (SOIL AND AQUEOUS MATRICES) PAH COMPOUNDS ONLY

| Matrix | # of Analyses | % Rec Range | Control Limits | # Within Limits | # Outside Limits | RPD Range | RPD Control Limits | # Within Limits | # Outside Limits |
|---|---|---|---|---|---|---|---|---|---|
| SOIL MATRICES | | | | | | | | | |
| | | | | - - Naphthalene - - | | | | | |
| ATS-CAR | 2 | 24-26 | 30-140 | 0 | 2 | 8 | 50 | 1 | 0 |
| SBR-CAR | 4 | 7-20 | 30-140 | 2 | 2 | 22-25 | 50 | 2 | 0 |
| SBR-IN | 4 | 59-89 | 30-140 | 4 | 0 | 3-12 | 50 | 2 | 0 |
| SPL | 4 | 44-51 | 30-140 | 4 | 0 | 15 | 50 | 2 | 0 |
| SPL-CO | 2 | 72-78 | 30-140 | 2 | 0 | 8 | 50 | 1 | 0 |
| SPH | 6 | 42-74 | 30-140 | 6 | 0 | 3-7 | 50 | 3 | 0 |
| SWL-CO | 2 | 60-62 | 30-140 | 2 | 0 | 3 | 50 | 1 | 0 |
| SWH-CO | 4 | 69-77 | 30-140 | 4 | 0 | 3-11 | 50 | 2 | 0 |
| SWH-FO | 2 | 59-82 | 30-140 | 2 | 0 | 33 | 50 | 1 | 0 |
| SWH-FPC | 6 | 57-63 | 30-140 | 6 | 0 | 2-8 | 50 | 3 | 0 |
| SWL-FS | 12 | 56-108 | 30-140 | 12 | 0 | 0-39 | 50 | 6 | 0 |
| SWH-FS | 2 | 69-70 | 30-140 | 2 | 0 | 1 | 50 | 1 | 0 |
| SWH-WS | 6 | 44-77 | 30-140 | 6 | 0 | 4-13 | 50 | 3 | 0 |
| | | | | - - 4-Chloro-3-methylphenol - - | | | | | |
| ATS-CAR | 2 | 33-35 | 26-103 | 2 | 0 | 6 | 50 | 1 | 0 |
| SBR-CAR | 4 | 11-29 | 26-103 | 1 | 3 | 9-27 | 50 | 2 | 0 |
| SBR-IN | 4 | 73-85 | 26-103 | 4 | 0 | 4-10 | 50 | 2 | 0 |
| SPL | 0 | - | 26-103 | - | - | - | 50 | - | - |
| SPL-CO | 2 | 84-87 | 26-103 | 2 | 0 | 4 | 50 | 1 | 0 |
| SPH | 4 | 46-57 | 26-103 | 4 | 0 | 5-16 | 50 | 2 | 0 |
| SWL-CO | 2 | 55-61 | 26-103 | 2 | 0 | 10 | 50 | 1 | 0 |
| SWH-CO | 4 | 65-68 | 26-103 | 4 | 0 | 2-5 | 50 | 2 | 0 |
| SWH-FO | 2 | 44-66 | 26-103 | 2 | 0 | 40 | 50 | 1 | 0 |
| SWH-FPC | 6 | 50-72 | 26-103 | 6 | 0 | 3-8 | 50 | 3 | 0 |
| SWL-FS | 12 | 48-87 | 26-103 | 12 | 0 | 0-29 | 50 | 6 | 0 |
| SWH-FS | 2 | 54-55 | 26-103 | 2 | 0 | 2 | 50 | 1 | 0 |
| SWH-WS | 6 | 46-73 | 26-103 | 6 | 0 | 7-13 | 50 | 3 | 0 |

TABLE 6-4. (CONTINUED)

| Matrix | # of Analyses | % Rec Range | Control Limits | # Within Limits | # Outside Limits | RPD Range | RPD Control Limits | # Within Limits | # Outside Limits |
|---|---|---|---|---|---|---|---|---|---|
| SOIL MATRICES | | | | | | | | | |
| | | | | - - Acenaphthene - - | | | | | |
| ATS-CAR | 2 | 20-21 | 31-137 | 0 | 2 | 5 | 50 | 1 | 0 |
| SBR-CAR | 4 | 5-17 | 31-137 | 0 | 4 | 18-27 | 50 | 2 | 0 |
| SBR-IN | 4 | 94-121 | 31-137 | 4 | 0 | 8-11 | 50 | 2 | 0 |
| SPL | 4 | 67 | 31-137 | 4 | 0 | 0 | 50 | 2 | 0 |
| SPL-CO | 2 | 83-85 | 31-137 | 2 | 0 | 2 | 50 | 1 | 0 |
| SPH | 6 | 68-87 | 31-137 | 6 | 0 | 6-22 | 50 | 3 | 0 |
| SWL-CO | 2 | 68-81 | 31-137 | 2 | 0 | 17 | 50 | 1 | 0 |
| SWH-CO | 4 | 52-113 | 31-137 | 4 | 0 | 32-74 | 50 | 1 | 1 |
| SWH-FO | 2 | 64-121 | 31-137 | 2 | 0 | 62 | 50 | 0 | 1 |
| SWH-FPC | 6 | 66-107 | 31-137 | 6 | 0 | 3-31 | 50 | 3 | 0 |
| SWL-FS | 12 | 30-104 | 31-137 | 11 | 1 | 4-70 | 50 | 5 | 1 |
| SWH-FS | 2 | 78 | 31-137 | 2 | 0 | 0 | 50 | 1 | 0 |
| SWH-WS | 6 | 34-72 | 31-137 | 6 | 0 | 6-26 | 50 | 3 | 0 |
| | | | | - - 4-Nitrophenol - - | | | | | |
| ATS-CAR | 2 | 12-16 | 11-114 | 2 | 0 | 29 | 50 | 1 | 0 |
| SBR-CAR | 4 | 0-12 | 11-114 | 1 | 3 | 0-120 | 50 | 1 | 1 |
| SBR-IN | 4 | 41-97 | 11-114 | 4 | 0 | 26-64 | 50 | 2 | 0 |
| SPL | 0 | - | 11-114 | - | - | - | 50 | - | - |
| SPL-CO | 2 | 104-114 | 11-114 | 2 | 0 | 9 | 50 | 1 | 0 |
| SPH | 4 | 18-77 | 11-114 | 4 | 0 | 5-70 | 50 | 1 | 1 |
| SWL-CO | 2 | 56-68 | 11-114 | 2 | 0 | 19 | 50 | 1 | 0 |
| SWH-CO | 4 | 61-186 | 11-114 | 2 | 2 | 18 | 50 | 2 | 0 |
| SWH-FO | 2 | 58-71 | 11-114 | 2 | 0 | 20 | 50 | 1 | 0 |
| SWH-FPC | 6 | 19-99 | 11-114 | 6 | 0 | 30-108 | 50 | 2 | 1 |
| SWL-FS | 12 | 42-106 | 11-114 | 12 | 0 | 2-58 | 50 | 5 | 1 |
| SWH-FS | 2 | 23-44 | 11-114 | 2 | 0 | 63 | 50 | 0 | 1 |
| SWH-WS | 6 | 49-96 | 11-114 | 6 | 0 | 10-30 | 50 | 3 | 0 |

TABLE 6-4. (CONTINUED)

| Matrix | # of Analyses | % Rec Range | Control Limits | # Within Limits | # Outside Limits | RPD Range | RPD Control Limits | # Within Limits | # Outside Limits |
|---|---|---|---|---|---|---|---|---|---|
| SOIL MATRICES | | | | | | | | | |
| | | | | - - Pyrene - - | | | | | |
| ATS-CAR | 2 | 3-4 | 35-142 | 0 | 2 | 29 | 50 | 1 | 0 |
| SBR-CAR | 4 | 0-6 | 35-142 | 0 | 4 | 0-200 | 50 | 1 | 1 |
| SBR-IN | 4 | 35-168 | 35-142 | 3 | 1 | 43-96 | 50 | 1 | 1 |
| SPL | 4 | 60-65 | 35-142 | 4 | 0 | 8 | 50 | 2 | 0 |
| SPL-CO | 2 | 70-71 | 35-142 | 2 | 0 | 1 | 50 | 1 | 0 |
| SPH | 6 | 23-110 | 35-142 | 4 | 2 | 0-32 | 50 | 3 | 0 |
| SWL-CO | 2 | 73-91 | 35-142 | 2 | 0 | 22 | 50 | 1 | 0 |
| SWH-CO | 4 | -413-61 | 35-142 | 0 | 4 | 387-453 | 50 | 0 | 2 |
| SWH-FO | 2 | 185-275 | 35-142 | 0 | 2 | 39 | 50 | 1 | 0 |
| SWH-FPC | 6 | -26-171 | 35-142 | 1 | 5 | 94-233 | 50 | 0 | 3 |
| SWL-FS | 12 | 2-187 | 35-142 | 8 | 4 | 2-109 | 50 | 2 | 4 |
| SWH-FS | 2 | 31-51 | 35-142 | 2 | 0 | 49 | 50 | 1 | 0 |
| SWH-WS | 6 | -12-65 | 35-142 | 2 | 4 | 2-169 | 50 | 1 | 2 |
| | | | | - - 2,3,5,6-TCP - - | | | | | |
| ATS-CAR | 2 | 5-7 | ** | - | - | 33 | ** | - | - |
| SBR-CAR | 4 | 0-8 | ** | - | - | NA | ** | - | - |
| SBR-IN | 4 | 7-50 | ** | - | - | 4-83 | ** | - | - |
| SPL | 0 | - | ** | - | - | - | ** | - | - |
| SPL-CO | 2 | 42-45 | ** | - | - | 7 | ** | - | - |
| SPH | 4 | 28-69 | ** | - | - | 0-49 | ** | - | - |
| SWL-CO | 2 | 16-18 | ** | - | - | 12 | ** | - | - |
| SWH-CO | 4 | -26-87 | ** | - | - | NA | ** | - | - |
| SWH-FO | 2 | -(110-30) | ** | - | - | NA | ** | - | - |
| SWH-FPC | 6 | 15-56 | ** | - | - | 24-81 | ** | - | - |
| SWL-FS | 10 | -49-111 | ** | - | - | NA | ** | - | - |
| SWH-FS | 2 | 24-30 | ** | - | - | 22 | ** | - | - |
| SWH-WS | 6 | -13-32 | ** | - | - | NA | ** | - | - |

TABLE 6-4. (CONTINUED)

| Matrix | # of Analyses | % Rec Range | Control Limits | # Within Limits | # Outside Limits | RPD Range | RPD Control Limits | # Within Limits | # Outside Limits |
|---|---|---|---|---|---|---|---|---|---|
| AQUEOUS MATRICES | | | | | | | | | |
| | | | | - - Naphthalene - - | | | | | |
| SWL-CDE | 2 | 56-60 | 30-120 | 2 | 0 | 7 | 40 | 1 | 0 |
| SWL-MW | 2 | 59-64 | 30-120 | 2 | 0 | 8 | 40 | 1 | 0 |
| SWH-MW | 4 | 72-81 | 30-120 | 4 | 0 | 4-5 | 40 | 2 | 0 |
| SWH-ATW | 4 | 28-80 | 30-120 | 3 | 1 | 1-76 | 40 | 1 | 1 |
| | | | | - - 4-Chloro-3-methylphenol - - | | | | | |
| SWL-CDE | 2 | 54-59 | 23-97 | 2 | 0 | 9 | 40 | 1 | 0 |
| SWL-MW | 2 | 69-72 | 23-97 | 2 | 0 | 4 | 40 | 1 | 0 |
| SWH-MW | 4 | 67-76 | 23-97 | 4 | 0 | 4-5 | 40 | 2 | 0 |
| SWH-ATW | 4 | 38-53 | 23-97 | 4 | 0 | 2-33 | 40 | 2 | 0 |
| | | | | - - Acenaphthene - - | | | | | |
| SWL-CDE | 2 | 69-70 | 46-118 | 2 | 0 | 1 | 40 | 1 | 0 |
| SWL-MW | 2 | 70-81 | 46-118 | 2 | 0 | 15 | 40 | 1 | 0 |
| SWH-MW | 4 | 80-85 | 46-118 | 4 | 0 | 2-6 | 40 | 2 | 0 |
| SWH-ATW | 4 | 64-83 | 46-118 | 4 | 0 | 6-16 | 40 | 2 | 0 |
| | | | | - - 4-Nitrophenol - - | | | | | |
| SWL-CDE | 2 | 59-91 | 10-80 | 1 | 1 | 43 | 40 | 0 | 1 |
| SWL-MW | 2 | 114 | 10-80 | 0 | 2 | 0 | 40 | 1 | 0 |
| SWH-MW | 4 | 67-92 | 10-80 | 2 | 2 | 1-9 | 40 | 2 | 0 |
| SWH-ATW | 4 | 40-84 | 10-80 | 2 | 2 | 1-28 | 40 | 2 | 0 |
| | | | | - - Pyrene - - | | | | | |
| SWL-CDE | 2 | 42-49 | 26-127 | 2 | 0 | 15 | 40 | 1 | 0 |
| SWL-MW | 2 | 83-89 | 26-127 | 2 | 0 | 7 | 40 | 1 | 0 |
| SWH-MW | 4 | 88-97 | 26-127 | 4 | 0 | 4-7 | 40 | 2 | 0 |
| SWH-ATW | 4 | 33-73 | 26-127 | 4 | 0 | 16-33 | 40 | 2 | 0 |

TABLE 6-4. (CONTINUED)

| Matrix | # of Analyses | % Rec Range | Control Limits | # Within Limits | # Outside Limits | RPD Range | RPD Control Limits | # Within Limits | # Outside Limits |
|---|---|---|---|---|---|---|---|---|---|
| AQUEOUS MATRICES | | | | | | | | | |
| | | | | - - 2,3,5,6-TCP - - | | | | | |
| SWL-CDE | 2 | 70-125 | ** | - | - | 56 | ** | - | - |
| SWL-MW | 2 | 80-85 | ** | - | - | 6 | ** | - | - |
| SWH-MW | 4 | 41-76 | ** | - | - | 16-58 | ** | - | - |
| SWH-ATW | 4 | 39-67 | ** | - | - | 10-16 | ** | - | - |

| | |
|---|---|
| ATS | Aqueous Treatment System |
| SBR | Slurry Bioreactor |
| SPL | Soil Pile Low Concentration |
| SPH | Soil Pile High Concentration |
| SWL | Soil Washing Low Concentration |
| SWH | Soil Washing High Concentration |

| | |
|---|---|
| CAR | Carbon Canister |
| IN | Influent |
| CO | Coarse Oversize |
| FO | Fine Oversize |
| FPC | Fine Particle Cake |
| FS | Feed Soil |
| WS | Wash Soil |
| CDE | Combined Dewatering Effluent |
| MW | Municipal Water |
| ATW | ATS Recycled Water |

Matrix spiking procedures are intended to mimic native compound behavior in the matrix of interest. While this may work well for aqueous matrices, (provided spiking concentrations are well below solubility limits), they are of more questionable value for soil matrices. Specifically, there are problems with soils because: 1) a spiking compound cannot be evenly distributed over and into the soil, and 2) the question of the compound reaching some kind of equilibrium in the soil before being extracted cannot be fully answered. Given these uncertainties associated with the soil spiking procedure, and the facts that surrogate recoveries were always within QC specifications and 2,3,5,6-TCP recoveries were generally within the acceptable range for penta recoveries, it can be postulated that laboratory extraction and analysis procedures were within acceptable limits.

COPPER, CHROMIUM, ARSENIC

Accuracy for copper, chromium, and arsenic (CCA) analyses of composited high- and low-concentration soil piles, and the particle size fractions of these samples, was assessed by laboratory matrix spike results (see Table 6-5). One arsenic recovery, associated with the analysis of some of the particle size fraction samples, was below the control limit. All other values were within QAPjP specifications indicating acceptable laboratory recovery and precision.

TOTAL RESIDUE

During the technical systems review of the laboratory, analytical balances used for weighing total residue were checked to insure calibrations met specifications. Standard operating procedure required a calibration check by calibrated laboratory weights used to ensure accuracy specifications did not exceed QAPjP requirements. All balances were then checked regularly during the course of the project to ensure total residue measurements were within specified requirements. These calibration checks served as a means of determining the accuracy of the total residue analysis.

PCDDs/PCDFs

Surrogate recoveries for all PCDD/PCDF analyses were within QAPjP specifications. Surrogates used in the PCDD/PCDF analysis are C13 derivatives of the congeners of interest. These surrogates therefore chemically represent total efficiency for extraction and analysis without need of matrix spike determinations.

NON-CRITICAL ANALYSES

There were no accuracy checks for the CEC analysis. Matrix spikes for total metals and EP Toxicity are reported in Table 6-5. As noted by this table, metal digestions were generally within specified control limits. Spikes for total recoverable petroleum hydrocarbons (TRPH) and total organic carbon (TOC) were all within specifications.

TABLE 6-5. QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, EP TOXICITY SOIL PILE SAMPLES (1)

| | ACCURACY | | | | | PRECISION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits | Total No. of Analyses | RPD Ranges | Control Limits | # Within Control Limits | # Outside Control Limits |
| Metals: | | | | | | | | | | |
| Arsenic | 2 | 55-87 | 75-125 | 1 | 1 | 2 | 1.3-5.7 | 0-20 | 2 | 0 |
| Barium | 1 | 108 | 75-125 | 1 | 0 | 1 | 18 | 0-20 | 1 | 0 |
| Cadmium | 1 | 100 | 75-125 | 1 | 0 | 1 | 4.3 | 0-20 | 1 | 0 |
| Chromium | 3 | 104-107 | 75-125 | 3 | 0 | 3 | 0.53-8.6 | 0-20 | 3 | 0 |
| Copper | 3 | 87-93 | 75-125 | 3 | 0 | 3 | 2.1-9.4 | 0-20 | 3 | 0 |
| Lead | 1 | 107 | 75-125 | 1 | 0 | 1 | 0.83 | 0-20 | 1 | 0 |
| Mercury | 1 | 86 | 75-125 | 1 | 0 | 1 | 7.8 | 0-20 | 1 | 0 |
| Selenium | 1 | 80 | 75-125 | 1 | 0 | 1 | 6.0 | 0-20 | 1 | 0 |
| Silver | 1 | 98 | 75-125 | 1 | 0 | 1 | 3.8 | 0-20 | 1 | 0 |
| TOTAL | 14 | | | 13 | 1 | 14 | | | 14 | 0 |
| Residue | N/A | -- | -- | -- | -- | 2 | 1.4-7.0 | 0-30 | 2 | 0 |
| EP Toxicity: | | | | | | | | | | |
| Arsenic | 1 | 119 | 75-125 | 1 | 0 | 1 | 3.0 | 0-20 | 1 | 0 |
| Barium | 1 | 122 | 75-125 | 1 | 0 | 1 | 4.6 | 0-20 | 1 | 0 |
| Cadmium | 1 | 102 | 75-125 | 1 | 0 | 1 | 7.7 | 0-20 | 1 | 0 |
| Chromium | 1 | 101 | 75-125 | 1 | 0 | 1 | 2.5 | 0-20 | 1 | 0 |
| Copper | 1 | 115 | 75-125 | 1 | 0 | 1 | 1.3 | 0-20 | 1 | 0 |
| Lead | 1 | 119 | 75-125 | 1 | 0 | 1 | 1.8 | 0-20 | 1 | 0 |
| Mercury | 1 | 100 | 75-125 | 1 | 0 | 1 | 19 | 0-20 | 1 | 0 |
| Selenium | 1 | 125 | 75-125 | 1 | 0 | 1 | 5.3 | 0-20 | 1 | 0 |
| Silver | 1 | 95 | 75-125 | 1 | 0 | 1 | 2.0 | 0-20 | 1 | 0 |

(1) Soil pile samples include the high and low composite samples, as well as the particle size fractions of the high and low soil pile samples.

PRECISION

Because the soil piles were composited prior to the demonstration all 12 of the high concentration soil pile samples and all 8 of the low concentration soil pile analyses were considered to be the same sample. For some of the analyses, however, split field samples were obtained for precision estimates. Table 6-5 shows the precision in terms of relative percent difference (RPD) for this split sample for the analyses of metals, residue, and EP Toxicity. All analyses shown in this table were within QAPjP specifications.

Analytical precision for penta and PAH analyses are shown by MS/MSD results in Tables 6-3 and 6-4. Field precision for penta as determined by the 12 replicate samples for the high concentration soil pile in terms of relative standard deviation is well within QAPjP specifications of 50%. Precision for the feed soil matrix is presented in the section on soil analyses. The feed soil is the same matrix as the soil pile, and therefore, these results are also comparable and provide additional verification of analytical precision for semi-volatile analyses in the soil piles.

COMPLETENESS

Completeness data for the soil pile are presented in Table 6-6. As shown in this table, all analyses were 100% complete.

### 6.4.2 Soil Washer Analyses

Two separate demonstrations were performed to evaluate the effectiveness of the BioTrol process on two separate soils with low and high concentrations of pentachlorophenol (400 and 1100 PPM, respectively). Characteristics of these two different soils are discussed in detail in the main body of the report. Both solid and aqueous matrices were produced as a result of the BioTrol soil washing procedure. The separate fractions were designated as feed soil, washed soil, fine particle cake, coarse oversize, fine oversize, and combined dewatering effluent. Municipal water feeding into the system was also analyzed to complete the mass balance equations. Analyses performed for each of these tests included the following parameters; penta, PAHs, Cu, Cr, As, total residue, PCDDs/PCDFs, total metals, total organic carbon (TOC), total recoverable petroleum hydrocarbon (TRPH), EP Toxicity, and the Toxicity Characteristic Leaching Procedure (TCLP).

ACCURACY

PENTACHLOROPHENOL AND PAHs

Surrogate spike summary data are presented in Tables 6-1 and 6-2 for all semivolatile analyses. Some samples were outside QAPjP specifications. Matrix effects are probably why there were problems with surrogate recovery. The two surrogate compounds which gave particular problems were 2-fluorophenol and p-terphenyl-d14. The criteria used for acceptability of data based upon surrogate recovery are explained in the following paragraph. If surrogate spike data did

TABLE 6-6. COMPLETENESS SOIL PILES

| Analysis | High Concentration Soil Pile | | | | Low Concentration Soil Pile | | | |
|---|---|---|---|---|---|---|---|---|
| | Projected | Satisfactory Analysis | Percent Complete | QAPjP Objective | Projected | Satisfactory Analysis | Percent Complete | QAPjP Objective |
| - - Critical - - | | | | | | | | |
| Pentachlorophenol | 13 | 13 | 100 | 90 | 9 | 9 | 100 | 90 |
| PAHs | 13 | 13 | 100 | 90 | 9 | 9 | 100 | 90 |
| Cu, Cr, As | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |
| Total Residue | 13 | 13 | 100 | 90 | 9 | 9 | 100 | 90 |
| Dioxin/Furan | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |
| - - Non-Critical - - | | | | | | | | |
| Total Metals | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |
| TOC | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |
| Total Rec Petro Hydro | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |
| Cation Exchange Capacity | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |
| EP TOX | 1 | 1 | 100 | 90 | 1 | 1 | 100 | 90 |

not meet these specifications, results from those specific samples were not used in determining project objectives.

Data were considered acceptable for use if one surrogate was outside its acceptable recovery range or if two surrogates were outside the acceptable range, provided they were not both the same class of compounds, (e.g., two acids or two bases). For example, if penta or an acid PAH compound concentration was being evaluated then two base/neutral surrogates could be outside the recovery range, provided all acid surrogates are within acceptable limits. This same rule applies for base/neutral compounds of interest but instead of base/neutral surrogates being outside their acceptable recovery range, surrogate recoveries for two acid surrogates can be outside recovery specifications and all base/neutral surrogate compounds must be within acceptable limits. Because the laboratory always performed necessary re-extractions when surrogates were outside limits of acceptability, it is probable that matrix interferences account for the sometimes poor recoveries of 2-fluorophenol and p-terphenyl-d14.

Matrix spike/matrix spike duplicate (MS/MSD) data are presented in Tables 6-3 and 6-4. As noted in the section on soil pile analyses, matrix spike data are not useful for determining recovery efficiencies for penta on any of the soil matrices because spiking concentrations were well below native penta concentrations. This occurred for almost all matrices analyzed from the soil washer. This was not the case for the PAHs; however, recovery results are of less interest because little information was gained from PAH analyses. Specifically, only very low concentrations of PAHs were found in any of the native feed soils, and consequently removal efficiencies for PAHs were only determined for very few compounds. The data for penta MS/MSD results are useful however for determining analytical precision. Additional information on MS/MSD data is presented in the section on soil pile analyses.

COPPER, CHROMIUM, ARSENIC

Accuracy for copper, chromium, and arsenic (CCA) was determined by the analysis of laboratory matrix spikes. Results are summarized in Table 6-7 for both aqueous and solid streams of the soil washer.

All but one arsenic and one chromium spike recovery were within the control limits defined by the QA objectives.

TOTAL RESIDUE

As described previously accuracy for total residue analyses was determined by balance calibration checks performed as part of the technical systems review as well as routine calibration checks conducted during the course of the project. Analytical balances were always within specification.

PCDDs/PCDFs

Accuracy for PCDD/PCDF analyses was based upon the surrogate spike recoveries. As noted in the previous section under soil pile analyses, matrix spike data were not required for PCDD/PCDF analyses since surrogates were

TABLE 6-7. QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, EP TOXICITY SOIL WASHER SAMPLES

| Parameter | ACCURACY | | | | | PRECISION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits | Total No. of Analyses | RPD Ranges | Control Limits | # Within Control Limits | # Outside Control Limits |
| Soil Samples(1) | | | | | | | | | | |
| Metals: | | | | | | | | | | |
| Arsenic | 10 | 75-110 | 75-125 | 10 | 0 | 10 | 1.2-9.6 | 0-20 | 10 | 0 |
| Barium | 8 | 75-117 | 75-125 | 8 | 0 | 8 | 0.39-20 | 0-20 | 8 | 0 |
| Cadmium | 8 | 96-119 | 75-125 | 8 | 0 | 8 | 0.83-9.1 | 0-20 | 8 | 0 |
| Chromium | 8 | 76-125 | 75-125 | 7 | 1 | 8 | 0.19-9.2 | 0-20 | 8 | 0 |
| Copper | 8 | 76-120 | 75-125 | 8 | 0 | 8 | 0.88-9.0 | 0-20 | 8 | 0 |
| Lead | 8 | 92-119 | 75-125 | 8 | 0 | 8 | 0.35-9.5 | 0-20 | 8 | 0 |
| Mercury | 3 | 86-95 | 75-125 | 3 | 0 | 3 | 7.8-12 | 0-20 | 3 | 0 |
| Selenium | 6 | 44-103 | 75-125 | 4 | 2 | 6 | 3.2-10 | 0-20 | 6 | 0 |
| Silver | 8 | 87-115 | 75-125 | 8 | 0 | 8 | 0.41-9.3 | 0-20 | 8 | 0 |
| TOTAL | 67 | | | 64 | 3 | 67 | | | 67 | 0 |
| Residue (% Solids) | N/A | -- | -- | -- | -- | 9 | 0-8.09 | 0-30 | 9 | 0 |
| EP Toxicity: | | | | | | | | | | |
| Arsenic | 2 | 84-119 | 75-125 | 2 | 0 | 2 | 3.0-6.7 | 0-20 | 2 | 0 |
| Barium | 2 | 103-122 | 75-125 | 2 | 0 | 2 | 3.2-4.6 | 0-20 | 2 | 0 |
| Cadmium | 2 | 90-102 | 75-125 | 2 | 0 | 2 | 7.7-9.3 | 0-20 | 2 | 0 |
| Chromium | 2 | 101-103 | 75-125 | 2 | 0 | 2 | 2.5-4.3 | 0-20 | 2 | 0 |
| Copper | 2 | 93-115 | 75-125 | 2 | 0 | 2 | 1.3-8.6 | 0-20 | 2 | 0 |
| Lead | 2 | 105-119 | 75-125 | 2 | 0 | 2 | 1.8-12 | 0-20 | 2 | 0 |
| Mercury | 2 | 85-100 | 75-125 | 2 | 0 | 2 | 2.1-19 | 0-20 | 2 | 0 |
| Selenium | 2 | 105-125 | 75-125 | 2 | 0 | 2 | 4.5-5.3 | 0-20 | 2 | 0 |
| Silver | 2 | 93-95 | 75-125 | 2 | 0 | 2 | 4.6-2.0 | 0-20 | 2 | 0 |
| Aqueous Samples(2) | | | | | | | | | | |
| Metals: | | | | | | | | | | |
| Arsenic | 10 | 67-94 | 75-125 | 9 | 1 | 10 | 1.3-10 | 0-20 | 10 | 0 |
| Barium | 8 | 96-104 | 75-125 | 8 | 0 | 8 | 0.61-4.9 | 0-20 | 8 | 0 |
| Cadmium | 8 | 98-113 | 75-125 | 8 | 0 | 8 | 0.9-8.7 | 0-20 | 8 | 0 |

(1) Soil samples include all solid streams from the low and high pile soil washing tests (SWL/SWH-CO/WS/FO/FPC/FS).
(2) Aqueous samples include aqueous streams from the low (SWL-CDE/MW) and high (SWH-CDE/MW/ATW) soil washing tests.
(3) The MS with 0% recovery was reported with a footnote stating that a post-digestion spike indicated matrix interference. No RPD was reported.
N/A Not applicable

TABLE 6-7. QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, EP TOXICITY SOIL WASHER SAMPLES (CONTINUED)

| Parameter | ACCURACY | | | | | PRECISION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits | Total No. of Analyses | RPD Ranges | Control Limits | # Within Control Limits | # Outside Control Limits |
| Aqueous Samples(2) Metals: (Cont'd) | | | | | | | | | | |
| Chromium | 8 | 105-113 | 75-125 | 8 | 0 | 8 | 0.17-5.5 | 0-20 | 8 | 0 |
| Copper | 8 | 96-106 | 75-125 | 8 | 0 | 8 | 0.83-5.4 | 0-20 | 8 | 0 |
| Lead | 8 | 98-109 | 75-125 | 8 | 0 | 8 | 0.67-10 | 0-20 | 8 | 0 |
| Mercury | 3 | 85-100 | 75-125 | 3 | 0 | 3 | 3.3-12 | 0-20 | 3 | 0 |
| Selenium | 9 | 0-102(3) | 75-125 | 6 | 3 | 8(3) | 8.1-17 | 0-20 | 8 | 0 |
| Silver | 2 | 95-106 | 75-125 | 2 | 0 | 2 | 6.5-14 | 0-20 | 2 | 0 |
| TOTAL | 64 | | | 60 | 4 | 63 | | | 63 | 0 |
| Residue (Total Solids) | N/A | -- | -- | -- | -- | 14 | 0.37-21 | 0-30 | 14 | 0 |

(1) Soil samples include all solid streams from the low and high pile soil washing tests (SWL/SWH-CO/WS/FO/FPC/FS).
(2) Aqueous samples include aqueous streams from the low (SWL-CDE/MW) and high (SWH-CDE/MW/ATW) soil washing tests.
(3) The MS with 0% recovery was reported with a footnote stating that a post-digestion spike indicated matrix interference. No RPD was reported.
N/A Not applicable

chemical counterparts of congeners of interest. All soil samples except one, SWH-WS-05-03, had acceptable recoveries for all surrogate compounds. This sample had recoveries below the lower control limit for all surrogates. Recoveries averaged around 20% (lower control limit = 40%) indicating that the results for this sample may be biased low due to inefficient extraction. This same sample, however, was re-extracted and results were about 40% higher. This extraction was still below acceptable QC limits indicating a possible matrix effect. Because this was the only sample with poor surrogate recovery very little impact is expected upon data quality.

NON-CRITICAL ANALYSES

Accuracy for total metals is shown by matrix spike recoveries in Table 6-7. Almost all analyses were within QAPjP specifications. Average recovery for TOC for all solid analyses as computed from surrogate spike data was 83%. This was well within the QAPjP objective of 65-135%. TOC recoveries for all aqueous matrices of the soil analyses were within the QAPjP specified control limits of 50-150%. Matrix spikes for TRPH solid and aqueous samples were within the specified control limits of 60-120%. EP Toxicity accuracy was determined by matrix spikes for metal analyses as shown in Table 6-7. Surrogate spike results for TCLP analyses are presented with the semivolatile matrices in Tables 6-1 and 6-2. As previously noted, surrogate data which were outside specified control limits were not used.

PRECISION

PENTACHLOROPHENOL

Precision for these two analyses was determined by taking the relative percent difference (RPD) of field and/or laboratory duplicates or the relative standard deviation (RSD) if 3 or more replicates were sampled and analyzed. Results of replicate measurements for the pentachlorophenol data for soil analyses are presented in Tables 6-8 and 6-9. In addition, as noted in the discussion on accuracy, MS/MSD data served as an additional measure of analytical precision (see Tables 6-3 and 6-4 for semivolatile data and Table 6-7 for other non-critical analyses).

As shown in Table 6-8, all but one group of replicate penta measurements were within the QAPjP precision specifications for every matrix in both the high and low concentration soil tests. The single replicate measurement that was outside the specifications was for the washed soil matrix in the low concentration soil demonstration. The projected precision specified in the QAPjP was based upon anticipated sampling and analytical variability associated with the semivolatile measurements. The observed variability was well under these specifications for one of the washed soil replicate measurements and well above specifications for the other duplicate pair. Because it is expected that there are no real matrix differences between these two tests, it appears that this one duplicate result is the only measurement outside the normal range of variability for the washed soil matrix.

TABLE 6-8. LOW CONCENTRATION SOIL DEMONSTRATION - PRECISION (FIELD DUPLICATES)

| Sample Type (Matrix) | | # of Replicate Msmt Pairs | RPD or RSD Range (%) | QAPjP Control Limits | Total Within Limits | Total Outside Limits |
|---|---|---|---|---|---|---|
| | | | - - Pentachlorophenol - - | | | |
| FS | | 2 | 8-26 | 30 | 2 | 0 |
| WS | | 2 | 6-151 | 30 | 1 | 1 |
| CO | | 1 | 7 | 30 | 1 | 0 |
| FO | | 1 | 21 | 30 | 1 | 0 |
| FPC | | 1 | 11 | 50 | 1 | 0 |
| MW | | ND | | 50 | - | - |
| CDE | | 1 | 32 | 50 | 1 | 0 |
| | | | - - Total Residue - - | | | |
| FS | | ND | | 30 | - | - |
| WS | | 3 | 1-22 | 30 | 3 | 0 |
| CO | | 2 | 5-10 | 30 | 2 | 0 |
| FO | | 1 | 8 | 30 | 1 | 0 |
| FPC | | ND | | 30 | - | - |
| MW | | ND | | 30 | - | - |
| CDE | | ND | | 30 | - | - |
| | | | - - Copper, Chromium, Arsenic Analyses - - | | | |
| FS | Cu | 1 | 6.7 | 20 | 1 | 0 |
| | Cr | 1 | 6.2 | 20 | 1 | 0 |
| | As | 1 | 49 | 20 | 0 | 1 |
| WS | Cu | 3 | 46-88 | 20 | 0 | 3 |
| | Cr | 3 | 15-64 | 20 | 1 | 2 |
| | As | 3 | 3-25 | 20 | 2 | 1 |
| CO | Cu | 1 | 15 | 20 | 1 | 0 |
| | Cr | 1 | 16 | 20 | 1 | 0 |
| | As | 1 | 141 | 20 | 0 | 1 |
| FO | Cu | 1 | 43 | 20 | 0 | 1 |
| | Cr | 1 | 20 | 20 | 1 | 0 |
| | As | 1 | 22 | 20 | 0 | 1 |
| FPC | Cu | 1 | 20 | 20 | 1 | 0 |
| | Cr | 1 | 16 | 20 | 1 | 0 |
| | As | 1 | 17 | 20 | 1 | 0 |

Msmt - Measurement
FS - Feed Soil
WS - Washed Soil
CO - Coarse Oversize
FO - Fine Oversize
FPC - Fine Particle Cake
MW - Municipal Water
CDE - Combined Dewatering Effluent
ND - Not Detected

TABLE 6-9. HIGH CONCENTRATION SOIL DEMONSTRATION - PRECISION (FIELD DUPLICATES)

| Sample Type (Matrix) | # of Replicate Msmts (pairs) | RPD or RSD Range (%) | QAPjP Control Limits | Total Within Limits | Total Outside Limits |
|---|---|---|---|---|---|
| | | - - Pentachlorophenol - - | | | |
| SPH | 12 | 38 | - | - | - |
| FS | 1 | 20 | 30 | 1 | 0 |
| WS | 1 | 29 | 30 | 1 | 0 |
| CO | 1 | 14 | 30 | 1 | 0 |
| FO | 1 | 7 | 30 | 1 | 0 |
| FPC | 1 | 37 | 50 | 1 | 0 |
| MW | ND | - | 50 | - | - |
| CDE | 2 | 14-25 | 50 | 2 | 0 |
| ATW | 1 | 19 | 50 | 1 | 0 |
| | | - - Total Residue - - | | | |
| FS | 2 | 1-22 | 30 | 2 | 0 |
| WS | 2 | 3-8 | 30 | 2 | 0 |
| CO | 2 | 1-2 | 30 | 2 | 0 |
| FO | 3 | 13-67 | 30 | 2 | 1 |
| FPC | 2 | 5-6 | 30 | 2 | 0 |
| MW | ND | - | 30 | - | - |
| CDE | ND | - | 30 | - | - |
| ATW | 1 | 4 | 30 | 1 | 0 |
| | | - - Copper, Chromium, Arsenic Analyses - - | | | |
| WS Cu | 1 | 9 | 20 | 1 | 0 |
| Cr | 1 | 25 | 20 | 0 | 1 |
| Ar | 1 | 70 | 20 | 0 | 1 |
| FO Cu | 1 | 63 | 20 | 0 | 1 |
| Cr | 1 | 38 | 20 | 0 | 1 |
| Ar | 1 | 15 | 20 | 1 | 0 |

Msmt - Measurement
SPW - Soil Pile High Concentration PCP
FS - Feed Soil
WS - Washed Soil
CO - Coarse Oversize
FO - Fine Oversize
FPC - Fine Particle Cake
MW - Municipal Water
CDE - Combined Dewatering Effluent
ATW - ATS Recycled Water
ND - Not Detected

Because this single result is high and variability measurements by duplicate samples were limited, it would suggest that overall variability may be higher than originally anticipated for the washed soil matrix. CCA measurements also showed somewhat higher variability for this matrix (see below). This increased variability, however, will not affect project objectives. The project design anticipated this type of problem by increasing the number of samples collected and analyzed so that increased sampling and analytical variability could be tolerated. While the number of valid sample analyses is less than the number planned (see completeness objectives below) the statistical evaluation as presented in Appendix C of the QAPjP shows that even with these increased sample and analytical variabilities, project objectives for evaluating process efficiency could still be achieved for the soil washing system. This statistical design, as described in the QAPjP, is of critical importance in determining the minimum number of required samples. Analysis of the washed soil samples showed project objectives for determining penta removal were within specified confidence limits. (See final report conclusions.)

OTHER CRITICAL AND NON-CRITICAL ANALYSES

Precision for total residue, copper, chromium, and arsenic is also presented in terms of RPD in Tables 6-8 and 6-9. In general, all measurements were within QAPjP specifications. (Again, some discrepancies were observed in the washed soil matrix.) Table 6-7 shows precision for additional non-critical measurements including total metals, and EP Toxicity and additional metals found in the aqueous matrices. All analyses were within QAPjP specifications for precision.

In addition PCDD/PCDF analyses met required precision specifications for duplicate samples. The PAH concentrations were so low that duplicate samples showed non-detectable PAHs. So few PAHs were detected in any of the samples that the lack of this precision estimate for this one parameter should have little effect upon the quality of the data collected in terms of project objectives. TOC, TRPH were non-critical measurements and therefore no precision data are available. TCLP data (a non-critical measurement), in terms of semivolatiles, also had primarily non-detectable compounds in the duplicate samples, and therefore, precision data are not considered critical for this parameter.

COMPLETENESS

Tables 6-10 and 6-11 present completeness values for all critical analyses. As noted by these tables, all analyses did not meet the specified completeness objective. The primary reason completeness objectives were not achieved was because of the reduced number of samples collected. This was because the soil had to be mixed in one large batch prior to starting the tests, and the estimated volume of soil fell short of the required volume to complete the demonstration. Therefore, once the soil was completely used up, new soil could not be obtained because it would be a new batch of soil and would not be representative of the test being conducted. Given the volume of soil required to complete the entire demonstration it is not unusual that the estimated volume fell short of the required testing volume. Even though the total number of samples was less than planned this shortage did not affect project objectives. It became apparent to project and QA management, after the project began, that the number of samples needed in order to obtain project objectives was less than the completeness value

TABLE 6-10. "COMPLETENESS SOIL WASHER"; LOW CONC. SOIL DEMONSTRATION

| Analysis | Proposed | | | | | Collected | | | | | Satisfactory Analysis | | | | | Percent Complete | | | | | QAPjP Objective | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - - Collected Solids - - | | | | | | | | | | | | | | | | | | | | | | | | |
| | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC |
| - - Critical - - | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pentachlorophenol | 11 | 11 | 11 | 11 | 11 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 73 | 73 | 73 | 73 | 73 | 90 | 90 | 90 | 90 | 90 |
| PAHs | 11 | 11 | 11 | 11 | 11 | 8 | 7 | 8 | 8 | 8 | 8 | 7 | 8 | 8 | 8 | 73 | 64 | 73 | 73 | 73 | 90 | 90 | 90 | 90 | 90 |
| Cu, Cr, As | 11 | 11 | 11 | 11 | 11 | | | | | | | | | | | | | | | | 90 | 90 | 90 | 90 | 90 |
| Total Residue | 11 | 11 | 11 | 11 | 11 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 73 | 73 | 73 | 73 | 73 | 90 | 90 | 90 | 90 | 90 |
| Dioxins/Furans | | 2 | 2 | 2 | 2 | | | | | | | | | | | | | | | | 90 | 90 | 90 | 90 | 90 |
| - - Non-Critical - - | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Metals | | 2 | 2 | 2 | 2 | | | | | | | | | | | | | | | | | | | | |
| TOC | 9 | 9 | 9 | 9 | 9 | | | | | | | | | | | | | | | | | | | | |
| Total Rec Petro Hydro | 9 | 9 | 9 | 9 | 9 | | | | | | | | | | | | | | | | | | | | |
| EP TOX | | 2 | 2 | 2 | 2 | | | | | | | | | | | | | | | | | | | | |
| TCLP semi dioxin/furan | | 2 | | | | | | | | | | | | | | | | | | | | | | | |
| | - - Collected Liquids - - | | | | | | | | | | | | | | | | | | | | | | | | |
| | MW | | CDE | | | MW | | CDE | | | MW | | CDE | | | MW | | CDE | | | MW | | CDE | | |
| - - Critical - - | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pentachlorophenol | | | 7 | 11 | | | | 7 | 11 | | | | 7 | 11 | | | | 100 | 100 | | | | 90 | 90 | |
| PAHs | | | 7 | 11 | | | | 7 | 11 | | | | 7 | 11 | | | | 100 | 100 | | | | 90 | 90 | |
| Cu, Cr, As | | | 7 | 11 | | | | | | | | | | | | | | | | | | | 90 | 90 | |
| Total Residue | | | 7 | 11 | | | | 3 | 8 | | | | 3 | 8 | | | | 43 | 73 | | | | 90 | 90 | |
| Dioxins/Furans | | | | 2 | | | | | | | | | | | | | | | | | | | 90 | 90 | |
| - - Non-Critical - - | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Metals | | | 2 | 2 | | | | | | | | | | | | | | | | | | | | | |
| TOC | | | 5 | 9 | | | | | | | | | | | | | | | | | | | | | |
| Total Rec Petro Hydro | | | 5 | 9 | | | | | | | | | | | | | | | | | | | | | |

FS - Feed Soil
WS - Washed Soil
CO - Coarse Oversize
FO - Fine Oversize
FPC - Fine Particle Cake
MW - Municipal Water
CDE - Combined Dewatering Effluent

TABLE 6-11. "COMPLETENESS SOIL WASHER"; HIGH CONC. SOIL DEMONSTRATION

| Analysis | Proposed | | | | | Collected | | | | | Satisfactory Analysis | | | | | Percent Complete | | | | | QAPjP Objective | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - - Collected Solids - - | | | | | | | | | | | | | | | | | | | | | | | | |
| | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC | FS | WS | CO | FO | FPC |
| - - Critical - - | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pentachlorophenol | 27 | 27 | 27 | 27 | 27 | 21 | 21 | 21 | 21 | 21 | 20 | 19 | 18 | 21 | 19 | 74 | 70 | 67 | 78 | 70 | 90 | 90 | 90 | 90 | 90 |
| PAHs | 27 | 27 | 27 | 27 | 27 | 21 | 21 | 21 | 21 | 21 | 20 | 16 | 18 | 21 | 19 | 74 | 59 | 67 | 78 | 70 | 90 | 90 | 90 | 90 | 90 |
| Cu, Cr, As | 27 | 27 | 27 | 27 | 27 | | | | | | | | | | | | | | | | 90 | 90 | 90 | 90 | 90 |
| Total Residue | 27 | 27 | 27 | 27 | 27 | 21 | 21 | 21 | 21 | 21 | 21 | 20 | 21 | 22 | 20 | 78 | 74 | 78 | 81 | 74 | 90 | 90 | 90 | 90 | 90 |
| Dioxins/Furans | | 3 | 3 | 3 | 3 | | | | | | | | | | | | | | | | 90 | 90 | 90 | 90 | 90 |
| - - Non-Critical - - | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | |
| Total Metals | | 6 | 6 | 6 | 6 | | | | | | | | | | | | | | | | | | | | |
| TOC | 25 | 25 | 25 | 25 | 25 | | | | | | | | | | | | | | | | | | | | |
| Total Rec Petro Hydro | 25 | 25 | 25 | 25 | 25 | | | | | | | | | | | | | | | | | | | | |
| EP TOX | | 6 | 6 | 6 | 6 | | | | | | | | | | | | | | | | | | | | |
| | - - Collected Liquids - - | | | | | | | | | | | | | | | | | | | | | | | | |
| | ATW | MW | CDE | | | ATW | MW | CDE | | | ATW | MW | CDE | | | ATW | MW | CDE | | | ATW | MW | CDE | | |
| - - Critical - - | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pentachlorophenol | | 15 | 15 | 27 | | | 12 | 12 | 22 | | | 11 | 12 | 22 | | | 73 | 80 | 81 | | | 90 | 90 | 90 | |
| PAHs | | 15 | 15 | 27 | | | 12 | 12 | 22 | | | 11 | 12 | 22 | | | 73 | 80 | 81 | | | 90 | 90 | 90 | |
| Cu, Cr, As | | 15 | 15 | 27 | | | | | | | | | | | | | | | | | | 90 | 90 | 90 | |
| Total Residue | | 15 | 15 | 27 | | | 12 | 12 | 21 | | | 11 | 8 | 14 | | | 73 | 53 | 52 | | | 90 | 90 | 90 | |
| Dioxins/Furans | | | | 3 | | | | | | | | | | | | | | | | | | 90 | 90 | 90 | |
| - - Non-Critical - - | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | | - - - - - - - - - - - | | | | |
| Total Metals | | | 3 | 6 | | | | | | | | | | | | | | | | | | | | | |
| TOC | | 13 | 13 | 25 | | | | | | | | | | | | | | | | | | | | | |
| Total Rec Petro Hydro | | 13 | 13 | 25 | | | | | | | | | | | | | | | | | | | | | |

FS - Feed Soil
WS - Washed Soil
CO - Coarse Oversize
FO - Fine Oversize
FPC - Fine Particle Cake
ATW - ATS Recycled Water
MW - Municipal Water
CDE - Combined Dewatering Effluent

specified in the QAPjP. As demonstrated by the conclusions presented in the report, objectives for the soil tests in terms of penta removal efficiency were not affected by the shortage of samples obtained and analyzed.

### 6.4.3 BioTrol Aqueous Treatment System Analyses

The BATS was run simultaneously with the soil washer. Water effluent from the soil washer was diverted into a holding tank for storage. This effluent was later used to demonstrate the effectiveness of the aqueous treatment system. The test was scheduled to last 12 days but was shortened to 10 days due to mechanical pump failure. Even though the test was shortened by several days, a sufficient number of samples was still collected to determine the efficiency of the system. The following analyses were conducted: Penta, PAHs, Cu, Cr, As, total residue, PCDDs/PCDFs, total metals, TRPH, total organic chloride, chloride ion, and chemical oxygen demand.

ACCURACY

Penta and PAH COMPOUNDS

Accuracy for the aqueous treatment system was evaluated by percent recovery for surrogate and matrix spike samples. Results for surrogate spikes for PAH and penta analyses are presented in Table 6-12. As noted in the discussion for soil analyses, the same criteria for evaluating surrogate spike recovery were used for the aqueous treatment samples. If the sample did not meet specified recovery criteria the result was not used for determining recovery efficiency.

As with the soil analyses, Terphenyl-d14 and 2-Fluorophenol were particularly difficult surrogates to recover. Because re-extractions were performed whenever a single surrogate was outside its recovery range, these poor recoveries should be attributed to matrix interferences.

In addition to the surrogate spike recoveries MS/MSD results are shown in Table 6-13. (Pentachlorophenol data are not included in this table.) Similar to the soil analyses, most PAH recoveries are within specified limits; however, the PAH removal efficiency for the aqueous treatment system is not critical or even very meaningful because most native PAH compounds were at extremely low concentrations. Therefore, they were of little significance. (Removal efficiency for PAHs in the aqueous treatment system was not calculated due to the low concentrations of compounds.)

Penta concentrations were very high in the native sample and matrix spikes were spiked too low to accurately determine recovery efficiencies. (See discussion in section on soil analyses.) Table 6-3, however, presents precision for penta recovery from MS/MSD data. Matrix spike data for penta are of little use in determining accuracy based on percent recovery.

TABLE 6-12. ACCURACY - SURROGATE SPIKES, AQUEOUS TREATMENT SYSTEM (ATS) INFLUENT AND EFFLUENT SAMPLES

| Aqueous Analyte | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits |
|---|---|---|---|---|---|
| NBZ | 98 | 0-98 | 35-114 | 97 | 1 |
| FBP | 98 | 51-110 | 43-116 | 98 | 0 |
| TPH | 98 | 8-73 | 33-141 | 64 | 34 |
| PHL | 98 | 7-96 | 10-94 | 96 | 2 |
| 2FP | 98 | 0-80 | 21-100 | 74 | 24 |
| TBP | 98 | 0-110 | 10-123 | 96 | 2 |
| FLT | 98 | 22-130 | 20-130 | 98 | 0 |

NBZ Nitrobenzene-d5
FBP 2-Fluorobiphenyl
TPH Terphenyl-d14
PHL Phenol-d5
2FP 2-Fluorophenol
TBP 2,4,6-Tribromophenol
FLT Fluoranthene-d10

TABLE 6-13. MS/MSDS FOR ORGANICS ON ATS EFFLUENT SAMPLES

| | MS % REC | MSD % REC | % RPD | QAPjP QC Limits Accuracy (% REC) | No. Within QC Limits |
|---|---|---|---|---|---|
| MS - EPA Sample No. ATSEFF073 Water | | | | | |
| Naphthalene | 59 | 88 | 39 | 40-120 | 2 |
| 4-Chloro-3-methylphenol | 60 | 71 | 17 | 23-97 | 2 |
| Acenaphthene | 68 | 90 | 28 | 46-118 | 2 |
| 4-Nitrophenol | 54 | 63 | 15 | 10-80 | 2 |
| Pyrene | 49 | 18 | 93 | 26-127 | 1 |
| 2,3,5,6-TCP | 38 | 45 | 17 | 10-110 | 2 |
| MS - EPA Sample No. ATSEFF091 Water | | | | | |
| Naphthalene | 72 | 82 | 13 | 40-120 | 2 |
| 4-Chloro-3-methylphenol | 66 | 56 | 16 | 23-97 | 2 |
| Acenaphthene | 75 | 82 | 9 | 46-118 | 2 |
| 4-Nitrophenol | 96 | 106 | 10 | 10-80 | 0 |
| Pyrene | 66 | 52 | 24 | 26-127 | 2 |
| 2,3,5,6-TCP | 54 | 54 | 0 | 10-110 | 2 |
| MS - EPA Sample No. ATSEFF083 Water | | | | | |
| Naphthalene | 77 | 67 | 14 | 40-120 | 2 |
| 4-Chloro-3-methylphenol | 59 | 65 | 10 | 23-97 | 2 |
| Acenaphthene | 72 | 68 | 6 | 46-118 | 2 |
| 4-Nitrophenol | 90 | 75 | 18 | 10-80 | 1 |
| Pyrene | 51 | 64 | 23 | 26-127 | 2 |
| 2,3,5,6-TCP | NA | NA | NA | 10-110 | Not Spiked |
| MS - EPA Sample No. ATSEFF072 Water | | | | | |
| Naphthalene | 94 | 101 | 7 | 40-120 | 2 |
| 4-Chloro-3-methylphenol | 84 | 94 | 11 | 23-97 | 2 |
| Acenaphthene | 118 | 123 | 4 | 46-118 | 1 |
| 4-Nitrophenol | 53 | 46 | 14 | 10-80 | 2 |
| Pyrene | 103 | 114 | 10 | 26-127 | 2 |
| 2,3,5,6-TCP | 56 | 68 | 19 | 10-110 | 2 |

* Precision objectives specified in QAPjP are for field, not analytical, duplicates.

As with the soil analyses, 2,3,5,6-TCP was used as a surrogate compound for penta recovery. While penta matrix spikes are non-representative due to the spiking concentration being too low, 2,3,5,6-TCP recovery should be considered as a surrogate for penta (this was noted in the QAPjP). Similar to the soil matrices, 2,3,5,6-TCP recoveries are within acceptable limits if compared to QC limits for penta. While it would be better to have penta recovery information for determining accuracy for penta, having designated 2,3,5,6-TCP in the QAPjP as an additional spiking compound proved beneficial because of the problem encountered with penta spiking. Based upon the recovery efficiencies for surrogate spikes, as well as the recovery efficiencies for PAH matrix spike compounds and for 2,3,5,6-TCP, it is reasonable to conclude that accuracy for penta and PAHs in the aqueous treatment samples was well within QAPjP specifications. Therefore, conclusions concerning removal efficiency for penta in the aqueous treatment system were calculated using acceptable quality data.

COPPER, CHROMIUM, ARSENIC and TOTAL RESIDUE

Accuracy for copper, chromium and arsenic (CCA) analysis of influent and effluent ATS samples was assessed by laboratory matrix spike results. Results are summarized in Table 6-14. Arsenic was the only metal having an outlier recovery value.

Accuracy for total residue measurements is not readily assessed by routine spiking procedures. The accuracy of the values may be affected by analysis performed past the method-recommended holding time. Most ATS samples were analyzed for total solids between one and 41 days past the hold time. However, these residue measurements were not used in the evaluation of the ATS performance, and therefore, they had minimal impact on the project technical objectives.

PCDDs/PCDFs

As with other matrices, accuracy for PCDDs/PCDFs was determined using recovery results for C13 isotopes for each of the congeners. All results were within QAPjP specifications. While these analyses were designated as secondary critical measurements, the data were not used in determining project objectives. The reason for dioxin analyses was to evaluate the quality of the effluent water; these analyses were not designated as part of the developer claims.

NON-CRITICAL ANALYSES

Spiked samples were used to assess accuracy for the non-critical analysis of chloride and additional metals (barium, cadmium, lead, mercury, selenium and silver, see Table 6-14). Only selenium showed any potential bias in recovery with four of ten spike recoveries below control limits. Since selenium was not detected in any of the effluent samples analyzed, the impact is limited to a potential bias in the reported detection limit. Two equipment blanks contained barium at 11.2-11.3 µg/l; sample concentrations ranged from 3-4 times higher.

TABLE 6-14. QC SUMMARY: PRECISION AND ACCURACY - COPPER CHROMIUM ARSENIC, NON-CRITICAL METALS, RESIDUE, CHLORIDE AQUEOUS TREATMENT SYSTEM SAMPLES

| | ACCURACY | | | | | PRECISION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits | Total No. of Analyses | RPD Ranges | Control Limits | # Within Control Limits | # Outside Control Limits |
| Metals: | | | | | | | | | | |
| Arsenic | 11 | 67-94 | 75-125 | 10 | 1 | 11 | 1.2-10 | 0-20 | 11 | 0 |
| Barium | 8 | 96-104 | 75-125 | 8 | 0 | 8 | 0.61-4.9 | 0-20 | 8 | 0 |
| Cadmium | 8 | 98-113 | 75-125 | 8 | 0 | 8 | 0.9-8.7 | 0-20 | 8 | 0 |
| Chromium | 8 | 105-113 | 75-125 | 8 | 0 | 8 | 0.17-5.5 | 0-20 | 8 | 0 |
| Copper | 8 | 96-106 | 75-125 | 8 | 0 | 8 | 0.83-5.4 | 0-20 | 8 | 0 |
| Lead | 8 | 98-109 | 75-125 | 8 | 0 | 8 | 0.67-10 | 0-20 | 8 | 0 |
| Mercury | 3 | 85-100 | 75-125 | 3 | 0 | 3 | 3.3-12 | 0-20 | 3 | 0 |
| Selenium | 10 | 0-102(1) | 75-125 | 6 | 4 | 9(1) | 8.1-17 | 0-20 | 9 | 0 |
| Silver | 2 | 95-106 | 75-125 | 2 | 0 | 2 | 6.5-14 | 0-20 | 2 | 0 |
| TOTAL | 66 | | | 61 | 5 | 65 | | | 65 | 0 |
| Residue | N/A | -- | -- | -- | -- | 15 | 0.37-21 | 0-30 | 15 | 0 |
| Chloride | 2 | 96.6-108 | N/A | 2 | 0 | 1 | 1.3 | N/A | 1 | 0 |

NOTES:

(1) The MS with 0% recovery was reported with a footnote stating that a post-digestion spike indicated matrix interference. No RPD was reported.

One chloride analysis exceeded the 28-day method holding time by 30 days. This analysis has little impact upon overall data quality.

## PRECISION

### PENTACHLOROPHENOL AND PAHs

Precision for these analyses was determined from laboratory and field splits. RPD and RSD determinations were obtained from duplicate and replicates samples. Results of these analyses showed all replicates were within specified QAPjP limitations. A table has not been included because there were no deviations.

### COPPER, CHROMIUM, AND ARSENIC

Precision for CCA analyses was measured by the relative percent difference (RPD) between spiked duplicates. As summarized in Table 6-14, all RPD values were within control limits.

### TOTAL RESIDUE

Precision for total solids was determined by the analysis of duplicate samples. As noted in Table 6-14, all reported RPD values were within QAPjP specifications.

Of the three field duplicates collected from the ATS influent and effluent streams, only one RPD exceeded the precision control limits.

### PCDDs/PCDFs

Precision for this measurement was evaluated by replicate sampling. One field duplicate for the aqueous treatment system samples had an RPD of 71%. This was outside QAPjP specifications. Because these analyses were not used in the determination of removal efficiency this result should have no effect on project objectives. The reason PCDD/PCDF analyses were performed was to determine the quality of the effluent water.

### NON-CRITICAL ANALYSES

Precision measurements for the additional metal and chloride were all within control limits. (See Table 6-14.)

## COMPLETENESS

Completeness results for the aqueous treatment system are presented in Table 6-15. Completeness for the field measurements associated with the aqueous treatment system are presented in Table 6-16. As seen by the data presented in these two tables, completeness fell short of the QAPjP objective. During the demonstration the test had to be shortened by two days because of pump failure, and consequent toxic shock experienced by the micro-organisms. While the test was shortened and proposed data were not collected, the results obtained were used to compute an average efficiency and associated range. As presented

TABLE 6-15. COMPLETENESS FOR AQUEOUS TREATMENT SYSTEM (ATS)

| Sample Location | Analytical Parameter | # of Samples for which Results are Satisfactory | # of Samples for which Results were Planned * | Completeness (%) | QAPjP Objective |
|---|---|---|---|---|---|
| Influent | Penta | 32 | 48 | 67 | 90 |
| | PAHs | 32 | 48 | 67 | 90 |
| | CCA | 37 | 48 | 77 | 90 |
| | Total Residue | 30 | 48 | 63 | 90 |
| | TRPH | 37 | 48 | 77 | 90 |
| | COD | 37 | 48 | 77 | 90 |
| | TOX | 6 | 6 | 100 | 90 |
| | CL | 6 | 6 | 100 | 90 |
| Effluent | Penta | 33 | 48 | 69 | 90 |
| | PAHs | 33 | 48 | 69 | 90 |
| | CCA | 37 | 48 | 77 | 90 |
| | Total Residue | 29 | 48 | 60 | 90 |
| | TRPH | 36 | 48 | 75 | 90 |
| | COD | 36 | 48 | 75 | 90 |
| | PCDD | 5 | 6 | 83 | 90 |
| | MTLS | 9 | 12 | 75 | 90 |
| | TOX | 6 | 6 | 100 | 90 |
| | CL | 6 | 6 | 100 | 90 |
| Carbon | Penta | 4 | 1 | 400 | 90 |
| | PAHs | 4 | 1 | 400 | 90 |
| | Total Residue | 4 | 1 | 400 | 90 |
| | PCDD | 0 | 1 | 0 | 90 |
| Bag Filter | No samples were collected of the bag filter residue | | | | |

* This number is based on a test of 12 days, however the test lasted only 10 days. This is the primary reason completeness (%) did not meet the QAPjP objective.

TABLE 6-16. ATS FIELD MEASUREMENTS: COMPLETENESS

| Measurement | Number of Measurements Taken | Number of Measurements Planned * | Completeness |
|---|---|---|---|
| Influent Flow Rate | 106 | 144 | 74% |
| Effluent Flow Rate | 100 | 144 | 69% |
| Nutrient Flow Rate | 98 | 144 | 68% |
| pH Chemicals Flow Rate | 1 | 2 | 50% |
| Influent pH | 32 | 24 | 133% |
| Effluent pH | 32 | 24 | 133% |
| Influent Temp | 32 | 24 | 133% |
| Effluent Temp | 32 | 24 | 133% |
| Power | 27 | 24 | 113% |
| Carbon Residue Weight | 1 | 1 | 100% |

*This number is based on a test of 12 days, however the actual test lasted only 10 days.

previously in the report, sufficient data were collected to complete the primary objective and determine the efficiency of the system for degrading penta. Because the concentrations of PAHs were often below the analytical detection limits, data were calculated for these compounds.

### 6.4.4 Slurry Bioreactor

The slurry bioreactor was the third system tested during this demonstration. Once a sufficient slurry had been collected from the soil washer (fine particle cake mixed with combined dewatering effluent) this slurry was used to demonstrate the efficiency of the slurry bioreactor for penta and PAH removal. (The main section of the report discusses the composition of this slurry.) The following critical analyses were performed: penta, PAHs, Cu,Cr,As, total residue, and PCDD/PCDFs. In addition the following non-critical analyses were also conducted: TRPH, total organic chloride, chloride ion, and chemical oxygen demand.

ACCURACY

PENTACHLOROPHENOL AND PAHS

Surrogate spike data for semivolatile analyses (water and soil fractions) are presented in Tables 6-17 and 6-18. All surrogate spikes were within QAPjP specifications. Similar to the soil analyses all matrix spikes were too low to determine recovery efficiency. The MS/MSD data are therefore presented for purposes of demonstrating analytical precision only. MS/MSD data in terms of RPD are presented in Table 6-3.

MS/MSD recoveries for PAH compounds and 2,3,5,6-TCP are included in Table 6-19. In general recoveries were within QAPjP specifications. As with the soil matrices 2,3,5,6-TCP was used as a surrogate for penta recovery. Because recovery of this compound was within specified limits for penta, and because 2,3,5,6-TCP should be chemically similar to penta, these data along with the surrogate spike data indicate that penta values for the slurry bioreactor samples are within acceptable limits.

TOTAL RESIDUE

Residue determinations were performed on the slurry samples after filtering through a 0.7 µm glass fiber filter. The resulting filtrate was analyzed for total solids (actually dissolved), and the filtered solid (filter cake) was analyzed for percent solids. Accuracy for residue measurements is not readily assessed by routine spike and control sample analysis. Accuracy for the total residue analyses was therefore determined by calibration checks for the analytical balance used to weigh the samples. Balance calibration was confirmed during the technical systems review at the subcontracting laboratory, and all determinations were within QAPjP specifications.

TABLE 6-17. ACCURACY - SURROGATE SPIKES
SLURRY BIOREACTOR (SOIL FRACTION)

| Analyte | Total Measurements | Percent Recovery Range | QC Control Limits | Total # Within Limits | Total # Outside Limits |
|---|---|---|---|---|---|
| Nitrobenzene-d5 | 29 | 28-73 | 23-120 | 29 | 0 |
| 2-Fluorobiphenyl | 29 | 41-100 | 30-115 | 29 | 0 |
| Terphenyl-d14 | 29 | 39-99 | 18-137 | 29 | 0 |
| Phenol-d5 | 29 | 32-66 | 24-113 | 29 | 0 |
| 2-Fluorophenyl | 29 | 38-75 | 25-121 | 29 | 0 |
| 2,4,6-Tribromophenol | 29 | 55-98 | 19-122 | 29 | 0 |
| Fluoranthene-d10 | 29 | 40-95 | 15-140 | 29 | 0 |

TABLE 6-18. ACCURACY - SURROGATE SPIKES
SLURRY BIOREACTOR (WATER FRACTION)

| Analyte | Total Measurements | Percent Recovery Range | QC Control Limits | Total # Within Limits | Total # Outside Limits |
|---|---|---|---|---|---|
| Nitrobenzene-d5 | 29 | 41-93 | 35-114 | 29 | 0 |
| 2-Fluorobiphenyl | 29 | 48-92 | 43-116 | 29 | 0 |
| Terphenyl-d14 | 29 | 44-83 | 33-141 | 29 | 0 |
| Phenol-d5 | 29 | 28-90 | 10-94 | 29 | 0 |
| 2-Fluorophenyl | 29 | 37-91 | 21-100 | 29 | 0 |
| 2,4,6-Tribromophenol | 29 | 51-105 | 10-123 | 29 | 0 |
| Fluoranthene-d10 | 29 | 47-92 | 20-130 | 29 | 0 |

TABLE 6-19. MS/MSD DATA FOR SLURRY BIOREACTOR INFLUENT (PAH COMPOUNDS ONLY)

| Compound | # of Analytes | % Rec Range | Control Limits | # Within Limits | # Outside Limits | RPD Range | RPD Control Limits | # Within Limits | # Outside Limits |
|---|---|---|---|---|---|---|---|---|---|
| AQUEOUS MATRICES | | | | | | | | | |
| Naphthalene | 6 | 55-70 | 30-120 | 6 | 0 | 1-4 | 40 | 3 | 0 |
| 4-Chloro-3-methylphenol | 6 | 47-75 | 23-97 | 6 | 0 | 4-14 | 40 | 3 | 0 |
| Acenaphthene | 6 | 56-71 | 46-118 | 6 | 0 | 0-10 | 40 | 3 | 0 |
| 4-Nitrophenol | 6 | 50-104 | 10-80 | 4 | 2 | 1-35 | 40 | 3 | 0 |
| Pyrene | 6 | 45-74 | 26-127 | 6 | 0 | 7-13 | 40 | 3 | 0 |
| 2,3,5,6-TCP | 6 | 28-49 | ** | - | - | 9-22 | 40 | - | - |

The accuracy of the residue determinations may be affected by analyses performed beyond the method-recommended holding times. All SBR filtrates were analyzed for total solids between 25-55 days past the hold time; all SBR solids were analyzed for percent solids between 13-39 days after the holding time expiration. Residue measurements were used in mathematically determining the organic constituent (penta and PAHs) concentrations in the total sample (after analyzing the filtrate and the filter cake separately). It is not possible to estimate the effect of the exceeded holding times; however, sealed samples were stored at 4°C at all times prior to analysis, thus minimizing moisture losses due to evaporation.

COPPER, CHROMIUM, ARSENIC

Accuracy was determined by the analysis of laboratory matrix spikes for copper and chromium. Table 6-20 shows these analyses to be under control. Arsenic was analyzed by method SW-6010, and there were not any spikes associated with the sample analyses of the SBR samples. All these slurry samples were treated as aqueous samples due to the nature of the samples and the low solids content.

NON-CRITICAL ANALYSES

Accuracy for additional metals (barium, cadmium, lead, mercury, selenium and silver), chloride and metals on the EP Toxicity leachates was determined by the analysis of matrix spikes (see Table 6-20). The one selenium spike (selenium not in any of the samples) associated with the effluent samples had a low recovery, reported with a note attributing it to matrix effect. All other recoveries were within control limits.

Two samples exceeded the 28-day hold time for chloride by five and seven days.

No accuracy data are available for COD or TRPH. Because these data were not used to determine project objectives no impact is expected on overall data quality. Matrix spikes for TOX on four samples resulted in two recoveries slightly above the control limits, but other results were within specifications.

PRECISION

All precision data for the analyses of the SBR are presented in Table 6-21. These data are based upon field duplicates, and therefore indicate combined sampling and analytical variability.

PENTACHLOROPHENOL

Precision was calculated by determining the relative percent difference (RPD) of measurement pairs for liquid and solid fractions of both the influent and effluent samples. RPDs are presented in Table 6-21. In addition, analytical precision is presented in Table 6-3 which shows the results of MS/MSD pairs. As shown by the results presented in Table 6-21, all but one sample was within the QAPjP specified precision. This specification was based upon the best estimate

TABLE 6-20. QC SUMMARY: PRECISION AND ACCURACY - COPPER, CHROMIUM, ARSENIC, NON-CRITICAL METALS, RESIDUE, CHLORIDE, EP TOXICITY SLURRY BIOREACTOR SAMPLES

| | ACCURACY | | | | | PRECISION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Total No. of Analyses | % Recovery Ranges | Control Limits (%) | # Within Control Limits | # Outside Control Limits | Total No. of Analyses | RPD Ranges | Control Limits | # Within Control Limits | # Outside Control Limits |
| Metals:(1) | | | | | | | | | | |
| Arsenic | 0 | NS(2) | 75-125 | 0 | 0 | 0 | NS(2) | 0-20 | 0 | 0 |
| Barium | 2 | 82-106 | 75-125 | 2 | 0 | 2 | 2.8-3.6 | 0-20 | 2 | 0 |
| Cadmium | 2 | 85-93 | 75-125 | 2 | 0 | 2 | 2.6-14 | 0-20 | 2 | 0 |
| Chromium | 2 | 88-98 | 75-125 | 2 | 0 | 2 | 2.3-4.3 | 0-20 | 2 | 0 |
| Copper | 2 | 76-83 | 75-125 | 2 | 0 | 2 | 2.7-4.3 | 0-20 | 2 | 0 |
| Lead | 2 | 91-100 | 75-125 | 2 | 0 | 2 | 1.9-3.9 | 0-20 | 2 | 0 |
| Mercury | 2 | 92-106 | 75-125 | 2 | 0 | 2 | 5.3-17 | 0-20 | 2 | 0 |
| Selenium | 1 | 30(3) | 75-125 | 0 | 1 | 1 | 24 | 0-20 | 0 | 1 |
| Silver | 2 | 103-113 | 75-125 | 2 | 0 | 2 | 6.2-6.4 | 0-20 | 2 | 0 |
| TOTAL | 15 | | | 14 | 1 | 15 | | | 14 | 1 |
| Residue-filtrate | N/A | -- | -- | -- | -- | 1 | 0.7 | 0-30 | 1 | 0 |
| -solids | N/A | -- | -- | -- | -- | 2 | 2.0-4.1 | 0-30 | 2 | 0 |
| EP Toxicity: | | | | | | | | | | |
| Arsenic | 1 | 90 | 75-125 | 1 | 0 | 1 | 4.3 | 0-20 | 1 | 0 |
| Barium | 1 | 97 | 75-125 | 1 | 0 | 1 | 17 | 0-20 | 1 | 0 |
| Cadmium | 1 | 93 | 75-125 | 1 | 0 | 1 | 5.5 | 0-20 | 1 | 0 |
| Chromium | 1 | 107 | 75-125 | 1 | 0 | 1 | 6.5 | 0-20 | 1 | 0 |
| Copper | 1 | 96 | 75-125 | 1 | 0 | 1 | 2.1 | 0-20 | 1 | 0 |
| Lead | 1 | 103 | 75-125 | 1 | 0 | 1 | 1.7 | 0-20 | 1 | 0 |
| Mercury | 1 | 113 | 75-125 | 1 | 0 | 1 | 5.6 | 0-20 | 1 | 0 |
| Selenium | 1 | 105 | 75-125 | 1 | 0 | 1 | 0.38 | 0-20 | 1 | 0 |
| Silver | 1 | 105 | 75-125 | 1 | 0 | 1 | 0.76 | 0-20 | 1 | 0 |
| Chloride | 3 | 85.9-103 | 75-125 | 3 | 0 | 3 | 1.1-5.3 | 0-20 | 3 | 0 |

NOTES:

(1) Slurry samples from the SBR were treated as aqueous samples for the analysis of metals.
(2) No spike recoveries were reported with the arsenic results of the SBR samples, analyzed by SW846 Method 6010.
(3) This recovery was reported with a footnote stating that the low recovery was due to matrix effect.

TABLE 6-21. PRECISION SLURRY BIOREACTOR
FIELD DUPLICATES

| Sample Type | # Msmt Pairs | Compounds Detected | RPD % | QAPjP Control Limits | Total Within Limits | Total Outside Limits |
|---|---|---|---|---|---|---|
| | | - - Pentachlorophenol - - | | | | |
| Liq Effluent | 1 | | 11 | 50 | 1 | 0 |
| Liq Influent | 1 | | 62 | 50 | 0 | 1 |
| Solid Effluent | 1 | | 4 | 30 | 1 | 0 |
| Solid Influent | 1 | | 16 | 30 | 1 | 0 |
| | | - - PAHs - - | | | | |
| Liq Effluent | 1 | undetected | | | - | - |
| Liq Influent | 1 | undetected | | | - | - |
| Solid Effluent | 1 | fluoranthene | 12 | 50 | 1 | 0 |
| | 1 | pyrene | 0 | 50 | 1 | 0 |
| Solid Influent | 1 | fluoranthene | 3 | 50 | 1 | 0 |
| | 1 | pyrene | 36 | 50 | 1 | 0 |
| | 1 | b anthracene | 27 | 50 | 1 | 0 |
| | 1 | chrysene | 13 | 50 | 1 | 0 |
| | | - - Copper, Chromium, Arsenic Analyses - - | | | | |
| Influent | 1 | As | 0 | 20 | 1 | 0 |
| | 1 | Cr | 1 | 20 | 1 | 0 |
| | 1 | Cu | 1 | 20 | 1 | 0 |
| Effluent | 1 | As | 6 | 20 | 1 | 0 |
| | 1 | Cr | 7 | 20 | 1 | 0 |
| | 1 | Cu | 5 | 20 | 1 | 0 |

b - Benzo
MSMT - Measurement
RPD - Relative Percent Difference

TABLE 6-21. PRECISION SLURRY BIOREACTOR FIELD DUPLICATES (CONTINUED)

| Sample Type | # Msmt Pairs | Compounds Detected | RPD % | QAPjP Control Limits | Total Within Limits | Total Outside Limits |
|---|---|---|---|---|---|---|
| | | -- Dioxins/Furans -- | | | | |
| Effluent | 1 | HxCDD | 8 | 40 | 0 | 0 |
| | 1 | HpCDD | 11 | 40 | 0 | |
| | 1 | OCDD | 16 | 40 | 0 | 1 |
| | 1 | PeCDF | 30 | 40 | 0 | |
| | 1 | HxCDF | 12 | 40 | 0 | 0 |
| | 1 | HpCDF | 32 | 40 | 0 | |
| | 1 | OCDF | 18 | 40 | 0 | 0 |
| | | -- Total Residue -- | | | | |
| Influent | 1 | | 4 | 30 | 1 | 0 |
| Effluent | 1 | | 30 | 30 | 1 | 0 |
| | | -- Metals -- | | | | |
| Effluent | 1 | Barium | 12 | 20 | 1 | 0 |
| | 1 | Lead | 3.9 | 20 | 1 | 0 |
| | | Mercury | 8.5 | 20 | 1 | 0 |
| | | -- TOX (NC) -- | | | | |
| Effluent | 1 | | 144 | 20 | 0 | 1 |
| | | -- CO | | 20 | 1 | 0 |
| Influent | 1 | | 35 | 40 | 1 | 0 |
| Effluent | 1 | | 4 | 40 | 1 | 0 |
| | | -- Chloride Ion (NC) | | | | |
| Effluent | 1 | | 1 | 10 | 1 | 0 |

Msmt - Measurement
NC - Non Critical Measurement
Note - Total Recoverable Petrolem Hydrocarbons (TRPH) were not detected in the field duplicate samples.

of sampling and analytical variability available when the QAPjP was written. As noted by the statistical calculations in appendix C of the QAPjP, however, a much larger variation was still acceptable in order to accomplish project objectives provided a large number of samples were obtained. (See section below on completeness.)

Conclusions concerning the efficiency of the process are not affected by this single precision result which was outside QAPjP specifications. Conclusions presented in the report on the efficiency of the slurry bioreactor are only an estimate of the best observed efficiency and are not used as supporting evidence of the developer's claim for the process. Only a small number of representative samples were obtained during the operation of the slurry bioreactor because the system was nutrient starved for a majority of the sampling period. This occurrence was only evident after samples had been collected and analyzed by the laboratory and the demonstration had been completed. Additional information concerning the slurry bioreactor efficiency can be found in section 6.2, entitled "Conclusions and Limitations of Data", and in the main body of the report.

PAHs

As shown in Table 6-21, all precision determinations are within the specified objective for any of the PAH compounds detected. It is therefore anticipated that variability due to precision error will have no effect upon conclusions concerning the efficiency of PAH destruction.

COPPER, CHROMIUM, ARSENIC

All precision determinations were well under the specifications presented in the QAPjP. No significant effect is therefore anticipated with relation to the conclusions presented (see Table 6-21).

TOTAL RESIDUE

Total residue precision for both influent and effluent samples were within QAPjP specifications based upon RPDs of duplicate pairs.

PCDD/PCDF

One field duplicate was analyzed for PCDDs/PCDFs as shown in Table 6-21. Sampling and analytical precision was well within QAPjP specifications for all congeners. A slurry matrix laboratory duplicate was also performed, resulting in RPD values for the various congeners ranging from 21-82%; the average RPD = 37.8%. (The QAPjP objective for method precision of the PCDD/PCDF analysis was an RPD = 40%.) PCDD/PCDF analysis was conducted only to estimate relative dioxin/furan levels in the effluent sample. While it was noted as a secondary critical measurement, it was not used to determine process efficiency. In addition, several (7) effluent samples were analyzed, so the concentration of dioxin/furan potentially exiting the SBR is well characterized. While the method precision for the laboratory duplicate shown above was not within QAPjP specifications for all congeners, the duplicate field sample showed total variability to be within specified limits. Based upon these results no significant data quality problem is expected.

NON-CRITICAL MEASUREMENTS

All duplicate samples for the non-critical measurements were within QAPjP specifications except for total organic chloride. This is the only measurement outside specified objectives, and it is not considered critical because conclusions presented in this report are based only upon data from critical analyses.

No data existed for precision of the total recoverable petroleum hydrocarbon analysis because all samples reported undetectable levels for this analysis.

COMPLETENESS

Completeness objectives are presented in Table 6-22 for all measurements performed during the evaluation of the slurry bioreactor. Based upon the original QAPjP calculations, completeness objectives were not achieved for all critical measurements. The definition for completeness as presented in RREL's more recent QA guidance documents suggests that completeness objectives must be based upon a statistical evaluation in relation to project needs for accomplishing project objectives in terms of decision making criteria. It is this latter definition of completeness that is more relevant to this project. As previously noted, Appendix C of the QAPjP presents a statistical evaluation which defines the number of samples required for achieving project objectives in terms of evaluating process efficiency based upon the analytical and sampling variability associated with those samples. Using this evaluation, project and QA personnel have now agreed that original completeness objectives were higher than necessary given the actual variability of these measurements. This statistical evaluation was also reviewed with RREL's QA Contractor prior to the demonstration and was found to be acceptable. These conclusions suggest that the completeness achieved from the analytically valid SBR data was within statistical specifications for determining whether the process was meeting the developer's claims.

REPRESENTATIVENESS

For purposes of this demonstration two samples were collected. Influent and effluent contaminant concentrations were measured and reported for all the above analyses. While the designated number of samples were collected and analyzed, it was discovered that a majority of these samples were collected prior to slurry activation. Since this is a biological system, organisms require an activation start-up period based in part upon residence time of the reactor. Calculations to determine this residence time and consequently to determine peak performance were used so that samples could be taken during the period of maximum performance. Unfortunately, it was discovered after analysis of these samples that peak performance could not be determined because this activation start-up period had been incorrectly estimated. The micro-organisms had experienced toxic shock, and process parameters had to be altered. Several samples were taken

TABLE 6-22. "COMPLETENESS" SLURRY BIOREACTOR

| Analysis | # of Samples Proposed | | # of Samples Collected | | # Samples with Satisfactory Analyses | | Percent Complete | | QAPjP Completeness Objective |
|---|---|---|---|---|---|---|---|---|---|
| | Influent | Effluent | Influent | Effluent | Influent | Effluent | Influent | Effluent | |
| -- Critical -- | | | | | L/S | L/S | | | |
| Pentachlorophenol | 18 | 18 | 15 | 15 | 14/14 | 15/15 | 78 | 83 | 90 |
| PAHs | 18 | 18 | 15 | 15 | 14/14 | 15/15 | 78 | 83 | 90 |
| Cu, Cr, As | 18 | 18 | 15 | 15 | 15 | 15 | 83 | 83 | 90 |
| Total Residue | | | | | | | | | |
| a) % Solids; Filter cake | 18 | 18 | 15 | 15 | 15 | 15 | 83 | 83 | 90 |
| b) TDS; Filtrate | 18 | 18 | 15 | 15 | 7 | 11 | 39 | 61 | 90 |
| Dioxins/Furans | | 8 | | 7 | | 7 | | 88 | 90 |
| EP TOX * | | | | | | 3 | | | |
| -- Non Critical -- | | | | | | | | | |
| Total Rec Petro HC | 16 | 16 | 15 | 15 | 15 | 15 | 94 | 94 | 90 |
| Tot Organic Chloride | 3 | 3 | 3 | 3 | 3 | 3 | 100 | 100 | 75 |
| Chloride Ion | 3 | 3 | 3 | 3 | 3 | 3 | 100 | 100 | 75 |
| Chem. Oxygen Demand | 16 | 16 | 15 | 15 | 15 | 15 | 94 | 94 | 75 |
| -- Additional SBR Samples (Carbon Canister) -- | | | | | | | | | |
| Pentachlorophenol | | 1 | | 1 | | 1 | | 100 | 90 |
| PAHs | | 1 | | 1 | | 1 | | 100 | 90 |
| Total Residue | | 1 | | 1 | | 1 | | 100 | 90 |
| Dioxins Furans | | 1 | | 1 | | 1 | | 100 | 90 |

*Collected; however this sample was not specified in original QAPjP
L/S - Liquid Fraction/Solid Fraction
CAR Carbon Canister

prior to this activation start-up period, and it became obvious from the final effluent samples collected that process efficiency was continuing to rise. Therefore, maximum efficiency could not be determined. While contaminant concentrations were believed to be representative of the matrix, they were not representative of peak sample performance as had been specified in the QAPjP. As a result of this problem, peak performance of the system could not be determined.

ADDITIONAL SBR SAMPLES

An additional SBR sample was collected from the carbon canister for analysis of pentachlorophenol, PAHs, total residue, and PCDDs/PCDFs. Completeness and precision objectives were achieved as specified for this sample. There were no matrix spikes performed for this sample, nor were they specified in the QAPjP, because this was not a critical measurement and results were not used for determining project objectives.

### 6.4.5 Blank Results

A series of equipment and method blank determinations were performed for all critical analyses. As noted in the QAPjP there were 7 equipment blanks collected and analyzed for pentachlorophenol, PAHs, and PCDDs/PCDFs. Of the analyses that were performed, no significant amount of contamination was detected except for one of the equipment blanks analyzed for PCDD/PCDF. The compound detected (OCDD at 28 ng/l) was less than five times the reporting limit and significantly below the sample concentrations reported for OCDD. Since this concentration was so low and was detected in only one of seven blanks, it is not expected to adversely affect the results. All other analyses for equipment blank and method blank samples indicated no detectable contamination.

## 6.5 SPECIAL STUDIES

During the course of the follow-up technical systems review conducted at the subcontractor laboratory by the contractor QA Manager, it was discovered that a significant number of samples had been extracted past their holding time. (The reasons for this occurrence are discussed in section 6.6 describing audit findings.) Because this is a cause of major concern, the contractor QA Manager and RREL QA Officer decided it was necessary to measure missed holding-time effects for each soil matrix sampled to determine if the data were still of sufficient quality for a SITE Demonstration project.

In order to evaluate the holding time effect, it was necessary to re-extract and re-analyze samples which were originally extracted within their specified holding times and then compare the analytical results. Holding time effects, however, need to be distinguished from sampling and analytical variability. This could be accomplished only by re-extracting replicate samples which were originally extracted within specified holding times.

Matrices which exceeded their required extraction holding times included washed soil, feed soil, fine particle cake, fine oversize, and coarse oversize,

all of which are solid matrices. Except for the slurry bioreactor samples, aqueous samples were not significantly affected, according to data received during this first review. In reference to the slurry bioreactor, all those samples were extracted past their holding times at intervals ranging from a few days to 3 weeks. This occurred due to problems encountered in first attempting to centrifuge and then switching to pressure filtration of samples prior to extraction. Problems of sample extraction were due to the unusual matrix encountered.

The contractor QA Manager specified that several soil samples be re-extracted. These samples represented all five solid matrices. In addition, several slurry samples were re-extracted for both solid and aqueous phases.

With the exception of the slurry samples, all the re-extracted samples were replicates of samples initially extracted and analyzed within holding time specifications, and they represented all matrices. Re-extraction of these replicate samples provided data representative of extractions up to six weeks past the holding time. Re-extracted slurry samples were treated somewhat differently as noted below.

The preceding paragraphs describe the holding time problems and methods which were used to evaluate analyte concentrations with respect to holding time. Results of these re-extractions were compared to results of the original extractions in order to determine if the time period past the holding time caused significant changes in target analyte concentrations. It was known that a large portion of the samples including each soil matrix was affected.

Briefly reviewing project objectives, it was stated that their purpose was to determine Pentachlorophenol (penta) and polynuclear aromatic hydrocarbon (PAH) removal efficiency in the soil washing, aqueous treatment, and slurry bioreactor processes. To determine removal efficiency, the input and output analyte concentrations must be known. Given the steady state nature of the process, final values of grab samples were to be averaged and sample variation was to be included in this final calculation. Statistical variation from sample to sample was to be accounted for by taking a large sample set. The number of samples obtained is therefore critical with respect to this final calculation.

The soil washing and slurry bioreactor samples were affected because these solid extracts were known to have missed their holding time extraction date. Because the total number of samples is critical with respect to determining input and output concentrations, questionable data with respect to holding time could not be discarded. If possible therefore, these data must be used and included in the efficiency calculation for all systems examined.

As discussed in the main section of this report, analyte concentrations in two of the soil matrices must be known to determine efficiency of the soil washing system. These include the feed soil and the washed soil matrix. The feed soil is obviously what goes into the system, and while four solid matrices come out of the soil washer, the washed soil is what previously has been designated as the "clean fraction." The other solid matrices, which include the coarse oversize, the fine particle cake, and the fine oversize, are <u>not</u> used to calculate process efficiency. The purpose of collecting these other fractions

was to determine overall mass balance, which was also a primary project objective.

Because all solid matrices, except the feed soil, were products of the treatment system, analyte concentrations may be expected to decrease over time (following collection), as biological and physical/chemical processes within any treated matrix (containing inocula and nutrients) may be expected to continue. Once extracted, however, these processes slow down and target analyte concentrations are expected to be more stable. Consequently, holding times specified in the QAPjP were primarily based on three conditions: 1) what was known about these samples, 2) what were thought to be reasonable time periods needed to extract the samples, and 3) specifications for holding times noted in SW-846.

The rate of decrease over time is unknown and of course will vary with respect to storage conditions. Keeping the samples at 4 degrees centigrade should slow compound degradation, but it will not stop it altogether. If this rate of decrease is significant when compared to sample concentrations, and degradation occurs in the time period between the specified holding time and the time the samples were actually extracted, then data from the extractions would not give accurate analyte concentrations at the time of sample collection. Efficiency of the process is based upon conditions of the sample in the field at the time of collection.

Results of the holding time studies are presented in Tables 6-23 to 6-27. Analyte concentrations in each of the solid matrices for the soil washing system are shown. The slurry matrix for the slurry bioreactor are not presented in these tables but are discussed below. Samples extracted within the holding time are compared to samples extracted several weeks passed their holding time. The time frame chosen for samples purposefully extracted past their holding times is a little longer than the actual extraction time of real samples, and it is a compromise between actual extraction conditions and a reasonable time period in which the laboratory could perform these re-extractions. Actual conditions for samples extracted past their holding times are always less than the time frame presented in these tables generated from the holding-time studies. These data therefore represent a worse case scenario.

Because the Demonstration was not originally set up to determine the effects of missed holding times, the number of samples we could use for this comparison was limited. Replicate samples were chosen when available, and fortunately most of the replicate samples in the study were extracted within the required holding time so that this comparison could be made. The number of replicates, however, is still limited, and therefore absolute statistical comparisons are difficult. The tables present mean values for each analyte concentration, along with the relative percent difference (RPD) or, if possible with triplicate samples, the relative standard deviation (RSD). Except where indicated, concentrations were within the instrument calibration range and surrogate concentrations were within the specified recovery ranges.

Feed soil concentrations represent analyte concentrations before treatment and therefore, as discussed, are critical for determining the process efficiency. As presented in Table 6-23, duplicate samples were available for comparison. As

TABLE 6-23. HOLDING TIME STUDY FOR FEED SOIL

| | Analyte Concentration (Extracted Within Hold Time) PPB | | | | Analyte Concentration (Extracted 50 Days After Hold Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|
| | SWH-FS-05-5 | SWH-FS-05-6 | mean | RPD % | SWH-FS-05-5 | SWH-FS-05-6 | mean | RPD % |
| Pentachlorophenol | *1420254 | *840000 | 1130127 | 51 | 881352 | 864889 | 873121 | 2 |
| Acenaphthene | 15180 | 15280 | 15230 | 1 | **23149 | **18803 | 20976 | 21 |
| Fluorene | 19937 | 20480 | 20208 | 3 | -- | **18385 | 18385 | N/A |
| Phenanthrene | 949694 | 92800 | 93747 | 20 | 100561 | 74500 | 87531 | 30 |
| Anthracene | 36189 | 15600 | 25895 | 80 | 40513 | 45030 | 42772 | 11 |
| Fluoranthene | 76556 | 76640 | 76598 | 1 | 75180 | 69577 | 72379 | 8 |
| Pyrene | 50081 | 49920 | 50000 | 1 | 60797 | 51301 | 56049 | 17 |
| Benzo(a)Anthracene | 13172 | 12880 | 13026 | 2 | **17329 | **12571 | 14950 | 32 |
| Chrysene | 22132 | 23840 | 22986 | 8 | **25233 | **24418 | 24826 | 4 |
| Benzo(b)Fluoranthene | **8755 | 16400 | 12578 | 61 | -- | -- | -- | -- |
| Benzo(k)Fluoranthene | **9176 | -- | 9176 | N/A | -- | -- | -- | -- |

* Value above calibration curve (no greater than 2X the highest calibration point)

** Value below calibration curve but above the method detection limit

-- Non detected values because dilutions were extremely large

TABLE 6-24. HOLDING TIME STUDY FOR WASHED SAND

| | Analyte Concentration (Extracted Within Hold Time) PPB | | | | | Analyte Concentration (Extracted 44 Days Afer Hold Time) PPB | | | | | | Analyte Concentration (Extracted 71 Days After Hold Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWH-WS 05-5 | SWH-WS 05-7 | SWH-WS 05-7(DUP) | mean | RSD % | SWH-WS 05-5 | SWH-WS 05-5(DUP) | SWH-WS 05-7 | SWH-WS 05-7(DUP) | mean | RSD % | SWH-WS 05-5 | SWH-WS 05-7 | mean | RPD % |
| Pentachlorophenol | 162000 | 124000 | 124000 | 136700 | 16 | 128000 | 244000 | 83000 | 94400 | 137400 | 54 | 116000 | 164000 | 140000 | 34 |
| Acenaphthene | 3400 | 3200 | *3200 | 3270 | 4 | 15000 | 12000 | — | 5300 | 10800 | 46 | 2800 | 3700 | 3250 | 28 |
| Fluorene | 3700 | 3200 | *3100 | 3300 | 10 | — | — | 5100 | *5600 | 5400 | 7 | — | 4000 | 4000 | N/A |
| Phenanthrene | 18000 | 13200 | 13200 | 14800 | 19 | 78600 | 67000 | 19200 | 21000 | 46500 | 66 | 14000 | 15000 | 14500 | 7 |
| Anthracene | 7300 | 6100 | *7600 | 7000 | 11 | 36000 | 30000 | 9200 | 10500 | 21400 | 63 | 5600 | 7700 | 6650 | 32 |
| Fluoranthene | 14000 | 11400 | 12200 | 12500 | 11 | 710000 | 60000 | 20000 | 19000 | 42500 | 63 | 10000 | 16000 | 13000 | 33 |
| Pyrene | 13000 | 11000 | 10000 | 11300 | 13 | 135000 | 113000 | 9000 | 11000 | 67000 | 99 | 13000 | 12000 | 12500 | 8 |
| Benzo(a)Anthracene | 3400 | 2000 | *2300 | 2600 | 29 | *13000 | — | 4000 | *4300 | 7100 | 72 | — | 3000 | 3000 | N/A |
| Chrysene | 6100 | 4000 | *4400 | 4800 | 23 | 29000 | 26000 | 6400 | *7100 | 17100 | 70 | — | 5000 | 5000 | N/A |
| Benzo(b)Fluoranthene | 2000 | 1300 | *1500 | 1600 | 23 | *13000 | 9600 | 2400 | *2600 | 6900 | 76 | — | — | — | — |
| Benzo(k)Fluoranthene | 2000 | 2000 | *2000 | 2000 | 0 | *10000 | 12000 | 2300 | *2500 | 6700 | 75 | — | — | — | — |

Duplicates represent analytical duplicates; samples 05-5 and 05-7 are field duplicates
PAH values for the second extraction of sample 05-5 are suspect
* Numbers above the instrument detection limit but below the calibration curve
— Nondetected values because dilutions were extremely large

TABLE 6-25. HOLDING TIME STUDY FOR COARSE OVERSIZE

| | Analyte Concentration (Extracted Within Hold Time) PPB | | | | | Analyte Concentration (Extracted 44 Days After Hold Time) PPB | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SWH-CO-05-5 | SWH-CO-05-6 | SWH-CO-05-7 | mean | RSD % | SWH-CO-05-5 | SWH-CO-05-6 | SWH-CO-05-7 | mean | RSD |
| Pentachlorophenol | 857796 | 1194077 | 916910 | 989594 | 18 | 1029609 | 1035484 | 785951 | 950348 | 15 |
| Acenaphthene | 23766 | 26488 | 16682 | 22312 | 23 | 21497 | **31505 | 30259 | 27754 | 20 |
| Fluorene | 24717 | 33379 | 20368 | 26155 | 25 | — | — | 30531 | 30531 | N/A |
| Phenanthrene | 122866 | 127417 | 98044 | 116109 | 14 | 82965 | 80862 | 80603 | 81477 | 2 |
| Anthracene | 53084 | 93807 | 122769 | 89887 | 39 | 100865 | 85694 | 99418 | 95326 | 9 |
| Fluoranthene | 76188 | 86943 | 64189 | 75773 | 15 | 80313 | 121349 | 92622 | 98095 | 22 |
| Pyrene | 61701 | 78752 | 57802 | 66085 | 17 | 60803 | 82808 | 47628 | 63746 | 28 |
| Benzo(a)Anthracene | 16355 | 21241 | 12359 | 16652 | 27 | 20099 | **23037 | 18758 | 20631 | 11 |
| Chrysene | 36397 | 61436 | 29912 | 42582 | 39 | 138559 | 41433 | 29890 | 69961 | 85 |
| Benzo(b)Fluoranthene | 8773 | 11520 | 6891 | 9061 | 26 | **11885 | **15414 | *9676 | 12325 | 24 |
| Benzo(k)Fluoranthene | 8619 | 9121 | 8076 | 8605 | 6 | **9039 | **14700 | *9652 | 11130 | 28 |

* Value above calibration curve (no greater than 2X the highest calibration point)

** Value below calibration curve but above the method detection limit

— Non detected values because dilutions were extremely large

TABLE 6-26. HOLDING TIME STUDY FOR FINE PARTICLE CAKE

| | Analyte Concentration (Extracted Within Hold Time) PPB | | | | Analyte Concentration (Extracted 44 Days After Hold Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|
| | SWH-FPC-05-5 | SWH-FPC-05-7 | mean | RPD % | SWH-FPC-05-5 | SWH-FPC-05-7 | mean | RPD % |
| Pentachlorophenol | 2458704 | 790000 | 1624352 | 103 | 432437 | 635470 | 533954 | 38 |
| Acenaphthene | 55619 | 27605 | 41612 | 67 | 49170 | 50248 | 49709 | 2 |
| Fluorene | 71478 | 34519 | 52999 | 69 | -- | 60185 | 60185 | N/A |
| Phenanthrene | *295570 | 140440 | 218005 | 71 | 86113 | 100614 | 93364 | 15 |
| Anthracene | 120366 | 54164 | 87265 | 76 | 108552 | 58695 | 83624 | 60 |
| Fluoranthene | *234977 | 113225 | 174101 | 70 | 72258 | 123134 | 97696 | 52 |
| Pyrene | *210150 | 102085 | 156118 | 69 | 55284 | 88646 | 71965 | 46 |
| Benzo(a)Anthracene | 63535 | 24584 | 44060 | 88 | 54715 | 55094 | 54905 | 1 |
| Chrysene | 90219 | 40321 | 65270 | 76 | 87587 | 79955 | 83771 | 9 |
| Benzo(b)Fluoranthene | 39892 | 18122 | 29007 | 75 | 41654 | 30991 | 36323 | 29 |
| Benzo(k)Fluoranthene | 34117 | **13956 | 24037 | 84 | 19668 | 23101 | 21384 | 16 |

* Value above calibration curve (no greater than 2X the highest calibration point)
** Value below calibration curve but above the method detection limit
-- Non detected values because dilutions were extremely large

TABLE 6-27. HOLDING TIME STUDY FOR FINE OVERSIZE

| | Analyte Concentration (Extracted Within Hold Time) PPB | | | | | Analyte Concentration (Extracted 44 Days After Hold Time) PPB | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SWH-FO-05-5 | SWH-FO-05-6 | SWH-FO-05-7 | mean | RSD % | SWH-FO-05-5 | SWH-FO-05-6 | SWH-FO-05-7 | mean | RSD |
| Pentachlorophenol | 14250000 | 1571423 | 2206666 | 2E+06 | 24 | 946390 | 1281840 | 1944560 | 1E+06 | 37 |
| Acenaphthene | 43828 | 42552 | 42382 | 42911 | 2 | **30314 | 34769 | **38657 | 34580 | 12 |
| Fluorene | 50797 | 52801 | 53490 | 52363 | 3 | — | 36987 | — | 36987 | N/A |
| Phenanthrene | *240796 | *249916 | *237121 | 242611 | 3 | 94390 | 108963 | 126622 | 109992 | 15 |
| Anthracene | 136066 | 153210 | 95168 | 128148 | 23 | 92758 | 77639 | 114691 | 95029 | 20 |
| Fluoranthene | 190792 | *185941 | 150367 | 175700 | 13 | 116220 | 139737 | 147269 | 134409 | 12 |
| Pyrene | 150325 | 155780 | 127808 | 144637 | 10 | 83759 | 81342 | 83496 | 82866 | 2 |
| Benzo(a)Anthracene | 38451 | 35023 | 45581 | 39685 | 14 | **22035 | 26248 | **28872 | 25718 | 13 |
| Chrysene | 73286 | 66490 | 84420 | 74732 | 12 | **38340 | 44833 | 53594 | 45589 | 17 |
| Benzo(b)Fluoranthene | 25202 | 22824 | 21152 | 23059 | 9 | **12619 | **15268 | **15122 | 14336 | 10 |
| Benzo(k)Fluoranthene | 24388 | 23526 | 21477 | 23130 | 6 | **12407 | **15767 | **15134 | 14436 | 12 |

* Value above calibration curve (no greater than 2X the highest calibration point)

** Value below calibration curve but above the method detection limit

— Non detected values because dilutions were extremely large

shown, relative percent differences which account for both sampling and analytical variability, are well within expected deviations for almost all compounds. As noted, no significant difference is detected between analyte concentrations in samples which were extracted within holding time compared to concentrations obtained for samples extracted 50 days past their holding time.

Because standard deviations were not computed for duplicate samples, a formal statistical test such as "Student's t" was not performed. It was necessary to compare each compound separately in order to detect patterns of degradation if they existed. For the feed soil matrix, this seemed to be the best approach, and all that was needed was a comparison of the means taking into account the relative percent difference for each sample set. Because feed soil is untreated, it is expected that holding time would be of less significance. Further statistical evaluations may be performed; however, they probably remain unnecessary and also may require assumptions about the data which may not be valid.

While a "t test" was performed for other matrices when possible, other observations about the data were required. For example, since no gross contamination was detected in the blank samples and micro-organisms are not expected to produce penta or PAHs, apparent increases in analyte concentrations are not presumed to be statistically significant. In addition, general observations showed that if one compound degraded in the time between extractions, almost all other compounds also degraded. This helped to determine if apparent losses of specific analytes were real. Additional observations and the implications of these observations are presented below. In cases where the "t test" was used to compare means, an alpha value of 0.05 was assumed significant.

Because feed soil did not show significant losses, data from the feed soil should be valid even if extracted past the original holding time. As discussed previously, all extractions were performed within the time period of the holding time study, and therefore these tables present a worse case situation.

The other critical matrix for determining treatment efficiency is the washed soil, in that this is what BioTrol claims to be "cleaned soil". Efficiency of the process is determined by comparing results of the washed soil to the feed soil. Table 6-24 shows results of the washed-sand holding-time study. All compounds detected showed no significant decrease in concentration between extraction periods. Relative percent differences were not as good as the soil matrix, and therefore a much wider variation is observed. In fact, some PAH compounds showed significantly higher concentrations when re-extracted. The reasons for this are unknown and are not easily explained. Comparisons of the mean concentrations for penta, however, showed no significant change. Since washed soil did not show significant losses, data should be valid even if samples were extracted past the original holding time. Statistical significance testing for the data generated during this phase of the holding time study was not performed because only duplicate samples could be compared. It is also difficult

to label any selected data as outliers. Therefore, concentrations of all compounds are presented.

Other matrices in the treated soil are important for mass balance determinations but do not affect treatment efficiency. Mass balance is difficult under the best conditions, and several factors can affect final calculations.

For the coarse oversize soil fraction (see Table 6-25) only one compound showed significant degradation as determined by Student's "t test" (alpha = 0.05). Phenanthrene appeared to have degraded by a minor amount, and in fact, showed only a slight difference in concentration when values were compared for pre- and post- extractions. Because this was the only compound concentration out of eleven compounds that significantly decreased, and because the micro-organisms or physical/chemical processes in question are not known to have any particular affinity for degrading phenanthrene, it appears more likely that no significant compound degradation occurred for this sample.

The fine particle cake fraction (see Table 6-26) showed a much larger variation between replicate samples, and in this regard, it was similar to what was observed for washed soil. Three compounds appeared to have experienced some degradation including penta, phenanthrene, and possibly pyrene. These degradations, however, may not be statistically significant, as only duplicate samples were compared and relative standard deviations were not computed. Nevertheless, because there are three compounds which appear to have degraded, and holding time is suspect, it is more difficult to rule out the possibility of biased data. Because the default position is that holding time affects compound concentration, (and these data do not prove otherwise), and because penta concentrations apparently decreased, it should be assumed that holding time affected the reported compound concentrations for a significant portion of these samples.

The final washed soil matrix which was examined was fine oversize (see Table 6-27). For this data set a statistically significant difference (alpha = 0.05) between the means is observed for all but one compound, anthracene. Not only do the mean concentrations differ significantly, but in all cases where there was a significant difference, individual analyte concentrations within a single sample went down over time. The evidence appears almost conclusive that degradation occurred with respect to time, and ranged from 30% to 50% depending upon the compound.

Given this additional information concerning the fine oversize and fine particle cake samples, determining the mass balance of target analytes within each of the soil matrices could be biased by the effect of missed holding times. Certainly mass balance is a difficult accomplishment in a project such as this, and missed holding times appear to cause additional confusion and possible bias in the final calculation.

For the above soil matrices, samples were extracted past their holding time, and therefore appropriate steps were taken to evaluate the effect. In several cases the evidence is not conclusive, but it certainly appears that holding time does <u>not</u> present a problem in determining treatment efficiency, although it will cause some difficulties in calculating mass balance. This mass balance

calculation is already known to be somewhat approximate. Unfortunately, studies such as these are not likely to produce conclusive results because they are often initiated after sample collection, and they are generally never included in the original project design. Therefore, decisions regarding utilization of available data are required based upon partial evidence. Recommendations concerning holding time effects have been clearly stated in the previous paragraphs, and are based solely upon the evidence presented.

Tables 6-28 and 6-29 show results of the holding time study conducted for the slurry samples. Extraction of these samples proved to be much more difficult than expected; penta concentrations were unknown and these types of samples had not been previously extracted. Originally, the samples were to be centrifuged, the solid and water portions were then to be extracted separately, and these extracts were to be combined for analysis. Centrifugation proved to be useless as solid and water portions could not be separated. Filtration was therefore conducted, but in performing this extra step, all samples were extracted past their initial holding time. Consequently, samples were extracted anywhere between several days to two weeks past holding times specified in the QAPjP.

Once samples were extracted, analysis was delayed until further examination of these extracts could be performed by the project QA Manager. This examination needed to be performed because the laboratory believed that concentration differences between the solid and water extracts differed greatly, and therefore it would probably be unwise to combine these extracts for analysis. In addition, these extracts looked extremely dirty, so the laboratory recommended a GPC clean-up prior to analysis. The QA Manager agreed with both of these recommendations. This decision was made in mid-December, 1989, and at the same time, laboratory personnel re-extracted the specified slurry samples for the holding time study. (It should be noted that the holding time study for the slurry samples compares samples extracted 1-2 weeks after their specified holding time to samples extracted approximately 6 weeks after their specified holding time.) During the analysis of these samples, the laboratory supervisor indicated that because the samples were so highly concentrated with contaminants, analyses were much more difficult than expected. Consequently, because of the analytical problems, results of the study were not available until mid-January, 1990, and therefore holding time evaluations were delayed.

Penta concentrations in the slurry samples were extremely high, and in order to get analyte concentrations within the linear range of the instrument, sample dilutions of 300X to 600X were required. As a result, surrogate information for each of these samples in the initial extraction set were lost. Samples could not be run at dilutions to quantitate the surrogate spikes since penta concentrations were extremely high. In attempting to perform surrogate quantitation, the laboratory supervisor soon realized that instrumentation would be unable to handle the overload, and resultant instrument down time became a critical issue. As a result, samples were diluted to attempt to quantify only the penta concentrations. Concentrations of other analytes and surrogates were not quantified.

TABLE 6-28. HOLDING TIME STUDY FOR SLURRY SOILIDS PHASE

| INFLUENT | Original Extract (13 Days Past the Holding Time) PPB | | | | Re-extract (77 Days Past the Holding Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|
| | SBR-IN-08-1 | SBR-IN-08-5 | mean | RPD % | SBR-IN-08-1 | SBR-IN-08-5 | mean | RPD % |
| Pentachlorophenol | 2600000 | 3200000 | 2900000 | 21 | 3400000 | 2900000 | 3150000 | 16 |
| Fluoranthene | 150000 | 280000 * | 215000 | 60 | 209000 * | 350000 * | 279500 | 50 |
| Pyrene | 150000 | 230000 * | 190000 | 42 | 154000 * | 380000 * | 267000 | 85 |

| EFFLUENT | Original Extract (13 Days Past the Holding Time) PPB | | | | Re-extract (77 Days Past the Holding Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|
| | SBR-EFF-08-1 | SBR-EFF-08-5 | mean | RPD % | SBR-EFF-08-1 | SBR-EFF-08-5 | mean | RPD % |
| Pentachlorophenol | 2900000 | 2600000 | 2750000 | 11 | 2300000 | 2400000 | 2350000 | 4 |
| Fluoranthene | -- | 89000 | 89000 | N/A | -- | -- | -- | -- |
| Pyrene | -- | 10000 | 10000 | N/A | -- | -- | -- | -- |

* Result is uncertain due to high dilutions

-- Non detected, but 300X to 600X dilutions were required to maintain PCP in calibration range

file: 6-28&29

TABLE 6-29. HOLDING TIME STUDY FOR SLURRY AQUEOUS PHASE

| INFLUENT | Original Extract (1-2 Weeks Past the Holding Time) PPB | | | | Re-extract (6 Weeks Past the Holding Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|
| | SBR-IN-08-1 | SBR-IN-08-5 | mean | RPD % | SBR-IN-08-1 | SBR-IN-08-5 | mean | RPD % |
| Pentachlorophenol | 32000 | 33000 | 32500 | 3 | 87000 | 43000 | ERR | 65 |

| EFFLUENT | Original Extract (1-2 Weeks Past the Holding Time) PPB | | | | Re-extract (6 Weeks Past the Holding Time) PPB | | | |
|---|---|---|---|---|---|---|---|---|
| | SBR-EFF-08-1 | SBR-EFF-08-5 | mean | RPD % | SBR-EFF-08-1 | SBR-EFF-08-5 | mean | RPD % |
| Pentachlorophenol | 110000 | 97000 | 103500 | 13 | 67000 | 75000 | 71000 | 11 |

It was decided it would be best to analyze all the initially extracted samples for penta, and then perform a re-extraction for the entire sample set. The purpose of the re-extraction was to extract smaller amounts of sample, thereby yielding extracts where surrogate spikes could be quantified at appropriate concentrations. This procedure was performed on a few selected samples which were then analyzed, and results were examined to ensure that the proper sample size was selected. The remaining sample set was then re-extracted and analyzed using these more appropriate sample sizes; however, the major drawback with this approach was that samples were extracted several months after their holding time. Nevertheless, these were the data which were eventually used for determining project objectives.

Presented in Tables 6-28 and 6-29 are slurry results from the first extraction sets and holding time studies which have no surrogates associated with the reported concentrations. Only duplicate samples were extracted, and the relative percent difference between the two samples is very large. Given these problems, concentrations can only be considered as approximations. Nevertheless, these data suggest no effect associated with holding time.

Penta concentrations in the aqueous slurry may also represent a maximum solubility threshold. Penta solubility in water is approximately 80,000 PPB, (reference: Merck Index, pH dependent). If degradation is occurring in the slurry sample, and penta concentrations are well above the maximum solubility of penta in water, the water portion of the slurry may always contain the same amount of penta, regardless of when it is extracted. Slurries are separated into water and solid samples by filtration just prior to extraction. Levels of penta are always well above the 80,000 PPB range in the solid samples, (see Table 6-28). Penta concentrations in the aqueous portion of the slurry range from 32,000 PPB to over 100,000 PPB. Penta extraction data from MS/MSD samples of aqueous solutions for the BioTrol liquids project range from 40-100%. Given this variability, along with instrument analytical variability, it is likely that the penta concentrations in Table 6-29 represent a maximum saturation in the aqueous portion of the slurry sample.

Because penta concentration levels differ by no significant amounts between the two slurry solid extractions, it is likely that holding time had no significant effect on concentrations for all the slurry samples. This is difficult to quantify because only duplicate samples were available for comparison and relative percent differences were fairly large. While it cannot be conclusively stated that holding time exhibits no sample bias, this effect is not noticeable within normal sampling and analytical variability. In addition, it is not believed that concentrations continued to decrease over time. Therefore, the slurry samples that were re-extracted at levels where surrogate information was available are not expected to experience holding time bias even though extractions are several months past their holding time. As noted, these were the samples that were used in the main body of the report.

In response to holding time concerns noted above, an additional data quality audit was performed several months after this study was conducted to determine if any additional data bias could be evaluated. During a data review conducted prior to this final audit, several concerns were noted and resolutions were

discussed between project and QA Managers which resulted in a better understanding of the conclusions to be designated in the final report.

Of primary concern was the issue of holding times which had been exceeded for several sample matrices. The holding time study described above had shown that holding time effects were not significant for the more critical soil matrices nor were they significant for the slurry samples. No holding time studies were conducted for aqueous samples because records obtained from the laboratory had indicated that aqueous samples had not exceeded their designated holding times. Review of the more recent project data received in the laboratory's final report showed that conclusions concerning soil and slurry matrices were still correct and holding time problems did not appear to be significant. In addition, laboratory records now showed that about 1/3 of the aqueous samples had exceeded their holding time.

The number of aqueous samples which were extracted past their holding time is extremely significant, therefore it was decided that holding time effect should be considered in order to save otherwise questionable data. A review of results for the same aqueous samples which had been extracted at two separate time periods was important to determine if differences in these data could cause bias in the reported conclusions. While no special study had been conducted, by coincidence because some surrogates did not meet specified recovery criteria, several aqueous samples were re-extracted past their holding time and results from these two extractions were compared. The Deputy Project Manager's statistical study of this somewhat limited group of samples indicated no significant effect due to holding time. While it could not be proven that holding time caused no bias, it was determined that if a holding time bias existed, this bias was within analytical and sampling variability. In addition to this statistical analysis, a review by the QA Manager of replicate samples analyzed within and outside their holding times indicated that effluent samples showed no effect due to holding time, but there did appear to be a bias caused by holding time for influent aqueous samples. (This difference could be due to the different nature of these two matrices.)

## 6.6 AUDITS and RESULTING QAPjP DEVIATIONS

### 6.6.1 BioTrol Soils Audit

An audit of the BioTrol Soils Project was conducted on September 26th and 27th, 1989. The EPA Auditor and Contracting QA Manager were present during the pre-test soil sampling and calibration operations.

There were two concerns and recommended corrective actions noted by the EPA Auditor. The first concern involved a change from the hourly collection of sample drum weights while sampling was in progress. Instead, full sample drums were weighed after collection. This change did not affect the collected data; however, it was also decided that 1 in 5 drums were to be weighed in duplicate in order to obtain a precision estimate of drum weights.

The second concern was the loss of measurement data on the oxidation-reduction potential of the combined dewatering effluent. A suitable redox meter

and probe did not arrive until the final day of sampling. Because this is a non-critical measurement, the loss of these data was not a major concern.

Other minor concerns noted were that split samples were performed in the laboratory and not in the field, contrary to specifications in the QAPjP, and less accurate alcohol thermometers had to be replaced by Hg thermometers. The EPA Auditor also recommended use of a sample log book and sample data sheets to insure a more permanent and traceable record.

Other changes in the QAPjP were required once field operations began. These changes included the following:

- Only a water and distilled water rinse were performed for decontamination between samples since only one auger was available. No methanol rinse or drying was performed between sampling since cross-contamination of composited soil samples was not considered a critical problem.

- Although rotameter calibration was carefully conducted with readings taken every 2 hours, it was of minimal benefit due to variable water flow through the meter. All water through the soil washing system, except municipal water, was measured more accurately by tank volume measurements. Municipal water accounts for 10% of total water when system is running at steady state conditions and was not expected to contain a significant amount of pollutants.

- The amount of nutrient added to the Aqueous Treatment System (ATS) was measured as total volume and the caustic used for pH adjustment was measured as total weight.

- The soil feed hopper was calibrated by hanging 3 separate weights from the belt scale. The manufacturer provided a conversion factor to obtain the measurements in pounds per hour. The speed of the feed belt was carefully timed to insure that static weighing would be close to the actual pounds per hour.

- The soil washing system was shut down several times due to higher creosote concentration causing the soil to cake inside the feed hopper. Samples were not taken during shutdown.

- Only 75% of the total data expected was collected because BioTrol ran out of soil and the ATS was shut down early due to pumping problems. Project and field managers however, believed that sufficient data were available to fulfill overall project objectives. This problem is discussed in detail in section 6.4.

The EPA Auditor noted that several changes made during the course of the project were not approved by the RREL QA officer; however, these changes were necessary and approved by the contractor QA Manager and are not expected to affect data quality. Although some decisions need to be made before the RREL QA officer can be consulted, these decisions are always discussed with the Project and QA Manager.

### 6.6.2 Laboratory Audit at 1st Subcontractor Laboratory and Field Audit of Slurry Bioreactor

The audit for the subcontracting laboratory was conducted on October 19th and 20th, 1989 by EPA and contractor QA personnel. Analyses being performed included total organic carbon (TOC), total organic halides (TOX), cation exchange capacity (CEC), chemical oxygen demand (COD), total recoverable petroleum hydrocarbons (TRPH), and analysis of chlorinated dibenzo dioxins/furans (PCDD). The only critical measurement was the analysis of PCDD. There were no analytical concerns for PCDD; however there were sampling concerns for PCDD and other concerns for the non-critical measurements.

The laboratory was instructed to perform PCDD analysis on 10 soil field splits. Dioxin analyses were not performed on the 10 split samples so there could be no field duplicates to assess precision. To resolve the oversight, 4 additional split samples, previously archived samples, were analyzed for dioxin. The samples chosen included one of each soil fraction: washed soil, fine particle cake, fine oversize, and coarse oversize.

A review of other PCDD analysis showed no field splits were scheduled for either the aqueous or slurry samples. Since sampling for the slurry bioreactor was ongoing, collection of the sampling plans and the field crew was notified. An additional aqueous sample was retrieved from the collected archives. Corrective action was initiated in response to these concerns.

The audit for on-site sampling of the slurry bioreactor was conducted by the EPA Auditor on October 23rd. Field personnel were conducting all operations as specified, and the audit rating was satisfactory.

### 6.6.3 Technical Systems Review (TSR) at Second Subcontractor Laboratory

On October 9th and 10th, 1989, a TSR was performed by EPA QA contractor. Concerns are noted below.

SAMPLE LOG-IN AND CUSTODY

Samples were properly logged into a bound notebook and entered into an electronic system. All shipment information was retained and the in-laboratory chain of custody forms were properly maintained. It was noted that one of the refrigerators used to store samples for this project was maintained at a temperature of 8°C, outside the specified range of less than 4°C.

LEACHING PROCEDURES

TCLP and EP forms were well organized and relatively complete except for information relating to the leaching fluid determination step for TCLP, documentation of extraction fluid preparation, and information regarding the initial liquid/solid separation step (e.g. volume of leachate). There were no means for monitoring or documenting the temperature of the room where leaching is performed. TCLP requires that the 18-hour leaching be performed around 22°C.

It was recommended that a recording thermometer be placed in the room where leaching occurs, and the chart documentation be retained.

EXTRACTION LABORATORY

The BioTrol SITE sample flow caused the laboratory to operate near or at their maximum capacity. In an effort to meet sample extraction holding times, two procedures were implemented that did not comply with Method 3550. Some soil samples were weighed and mixed with $Na_2SO_4$ in glass beakers with aluminum foil covers up to 24 hours prior to extraction. These were stored in a refrigerator at 4°C. This could lead to cross-contamination from external sources, and loss of unknown amounts of the more volatile PAH target analytes due to the inadequate aluminum foil seal. The second procedure involved concentrating 53 soil samples using a rotary evaporator. Method 3550 indicates only the use of the K-D technique for concentration of soil extracts. The main concern with using rotary evaporator concentration is that the recovery behavior of the targets may not be the same when compared to the K-D concentration technique. This would adversely affect data quality with respect to precision. In addition, method blank data for those extracts concentrated by rotary evaporation should be carefully examined because high-level sample extracts can cause analyte carryover into succeeding concentrations. Subsequent data analyses showed, however, that adequate recoveries of some analytes, including penta, were obtained using the rotary evaporator for extract concentration. It was recommended that the samples which did not comply with Method 3550 be re-extracted and use of the rotary evaporator discontinued.

Other minor concerns included: the storage of standards with some BioTrol samples in one refrigerator located in the extraction laboratory, two loose pages from the calibration notebook were found that did not contain proper analytical balance calibration information, references to both Method 8270 and Method 625 were found in the extraction laboratory paper work although these Methods are not entirely comparable, and the extraction logs were missing the date the samples were received into the extraction laboratory, the extract final volume, and (at times) the technician's initials. Finally, there was concern for the storage of extracts in round-bottom flasks for up to one week before drying and concentrating the samples. Without drying the extract with $Na_2SO_4$ prior to storage, there could be a loss of some components due to hydrolysis.

DETERMINATION OF PAHs AND PENTACHLOROPHENOL USING GC/MS

The GC/MS instrumentation appeared to be properly set up and maintained. A GC/MS maintenance log properly documented problems and routine maintenance of the system. Every entry was clearly written, dated, and initialed. The analyst stated that maintenance such as changing septa, liners, and breaking off of a few inches of column to optimize chromatography was being done on a routine basis, as required. There were two deviations from recommended GC/MC operating parameters listed in Method 8270. The mass spectrometer was being scanned from 45-500 amu, the recommended scan range is 35-500 amu. This difference in mass range scanning should not adversely impact data for this project because all PAH, surrogate, and MS analytes have quantitation ions well above m/e 45. A faster ramp rate (14°C/min) was also incorporated in the temperature program than is recommended in Method 8270 (10°C/min). A review of a GC/MS 50 ppm standard

analysis indicated that adequate chromatographic resolution was being achieved on the DB-5 0.32-mm bore, 30-meter, thick-film,fused silica capillary column which was used.

Surrogate recoveries met the objectives given in the QA Project Plan in every sample and blank reviewed. A total of seven surrogate compound recoveries were studied, including $D_{10}$-fluoranthene, which was added to more closely mimic the behavior of the PAHs of interest in this project. A review of MS/MSD recovery data yielded two compounds that were out of the QA Project Plan specified recovery control limits.

Pentachlorophenol and 4-nitrophenol recoveries were high in a MS sample analysis and 4-nitrophenol recovery was non-compliant in the MSD sample. The corresponding sample which was not spiked had not yet been analyzed by GC/MS at the time of the audit. It is possible that these analytes were present in the sample which could explain the outlier recovery data. In some cases, samples with MS/MSD pairs were not analyzed during the same shifts. It was recommended that a sample and its corresponding MS/MSD pair should be analyzed on the same shift so as to minimize variability of the data.

A QC check sample was not prepared or available for GC/MS analysis for this project. Method 8270 states that QC standards prepared from an independent source should be carried through the analytical system so as to provide information on the laboratory's ability to meet specified method accuracy criteria and that this must be done before sample analysis begins. QC check samples prepared with standards obtained from an independent source provide verification of calibration standard accuracy. Without a check standard prepared from a second source, it cannot be known whether the calibration standards are accurate. Hence, it might be stated that all ensuing analyses are of unknown accuracy. It was recommended that a check standard be prepared and analyzed in accordance with Method 8270.

RESIDUE DETERMINATIONS

Residue determinations are critical measurement parameters for this project. The QA Project Plan specified the use of EPA Method 160.3 for these determinations.

A serious problem not relating to laboratory performance was noted during this TSR. Some of the residue determinations were performed on samples which were preserved with acid. The laboratory was forced to take this approach since no separate aliquot without preservative was received, except for the PAH/penta aliquots, and many of these samples were completely consumed during extraction/analysis. Acidification of samples will likely produce biased results for the residue determinations through a variety of mechanisms. This was noted when comparing residue results for samples which were acidified with samples which were not acidified. Results between the two groups varied by a factor of four with the acidified samples having the higher results. Laboratory personnel noted that they would attempt to locate enough sample for the residue determination from either the extractable fraction or from the archive sample, and not perform any further residue analyses on acidified samples.

The balance used for weighing the residue samples was not checked for calibration on each day of use. Checking calibration of the balance is important since the balance is the primary standard for gravimetric procedures. It was recommended that the laboratory check and document calibration on each day the balance is used for residue determination.

No temperature record was kept for the drying oven used for the residue determinations. Method 160.3 requires that the samples are to be evaporated in the oven at 103-105°C. A check of the oven temperature during the TSR indicated that the temperature was 100°C. Since drying temperature can have significant effects on the accuracy of the method, it was recommended that the oven temperature be adjusted within the correct range and documented at the beginning and end of each batch of residue determinations.

Section 7.3 of Method 160.3 requires that a sample is to be evaporated, dried for one hour in the oven, then dried and desiccated to a constant weight. The procedure used was to dry the samples for 24 hours, desiccate for one hour, and weigh the samples once for the residue determination. This method is a significant deviation from the specified method. The impact to data quality with respect to accuracy due to this deviation is unknown since no QC samples for the evaluation of accuracy were analyzed (the method and QA Project Plan do not require the analyses of these samples). It was recommended that the laboratory adhere to method requirements with respect to drying procedures. Unfortunately, reanalysis of improperly processed samples may not be possible in all cases due to expiration of holding times.

One minor concern is an inadequate collection of duplicate samples on October 5th. A total of 41 samples were analyzed with only one duplicate analysis when the QA Project Plan specified one duplicate for every twenty samples.

TRACE METALS DETERMINATIONS

Copper, chromium, and arsenic determinations were considered critical measurements whereas Ba, Cd, Pb, Hg, Se, Ag were considered non-critical. Analytical runs were examined for all of the critical elements.

Two minor concerns which should not affect the quality of the determinations are that matrix spiking solution preparation information was not recorded, and the digestion logbook did not indicate the method used for sample digestion/preparation.

CONCLUSIONS

Since major concerns were noted with some of the critical measurements, this TSR indicated a rating of Conditional for the analytical efforts conducted at this subcontracting laboratory for the BioTrol Soils SITE project. Corrective actions and the initial TSR findings were discussed with the laboratory during a closing briefing. A Corrective Action Recommendation form was completed and is summarized below.

Nature of Concern:

1. Balance not checked for calibration (residue determination).
2. Drying to constant weight not performed (residue).
3. Improper storage of soil samples prior to preparation (foil covered beakers).
4. Samples not dried promptly after extraction.
5. Use of Roto-Vap for sample concentration.
6. No QC check standards prepared/analyzed for GC/MS.

Recommended Action:

1. Check and log balance calibration daily.
2. Dry samples to constant weight per method.
3. Discontinue this storage practice.
4. Dry samples promptly after extraction.
5. Use Kuderna-Danish apparatus in place of Roto-Vap as required. Document which samples by Roto-Vap.
6. Prepare/analyze QC check standards per method.

RESPONSE TO EPA PROJECT AUDIT DEBRIEFING

The laboratory implemented several changes in response to the concerns outlined during the audit debriefing. All changes were implemented with the concurrence of the contractor QA manager.

Responses to Identified Concerns:

1. Logbooks were started for the top loading balance to document that the calibration checks have taken place before each use.

2. Drying times were shortened and a constant weight was achieved.

3. All samples in the foil covered beakers (this included only those samples seen during the TSR and not prior samples) were prepared from the original sample bottles. The foil covered samples were not used.

4. All samples clearly showing any water were dried within two days of the TSR. Those not showing visible water were dried within a week. The heavy demands on the extraction laboratory staff precluded immediate drying of all samples. In the future, if samples need to sit in solvent, they will be dried before storage.

5. A total of 53 samples were concentrated by the Roto-vap procedure. It was not feasible to re-extract those samples within hold times so analyses were allowed to continue. As an independent check, laboratory personnel spiked solvent blanks with a subset of the analytes of interest and concentrated them with the roto-vap. This provided information on how the roto-vap affects recoveries. Since method blanks were already included with the samples, any contamination introduced by the technique could be determined. Prior experience indicates that recoveries should be good and contamination

minimal, but this approach allowed documentation for the compounds of interest.

6. Subsequent to the audit, QC check samples were prepared and analyzed.

### 6.6.4 Follow-up Audit of 2nd Subcontracting Laboratory

A follow-up audit was conducted, (November 2, 1989), by contracting QA management to document that the appropriate corrective action had been taken in response to concerns raised during the EPA audit, October 9, 1989.

The follow-up audit, in short, concluded that the laboratory had taken appropriate corrective action for each concern noted. Specifically, laboratory personnel were no longer using the roto-evaporator for any sample extracts, and they were in the process of assessing the effect roto-evaporation (compared to K-D concentration) would have on the specified samples. A study involving spiking blank extracts with project-specific target analytes was conducted. Given the time involved to extract 50 samples, it did not seem feasible to perform re-extractions, and in fact re-extracting, these samples would cause additional problems in meeting sample holding times. Problems with holding times are noted below. This approach was discussed during the audit as a means of corrective action.

A new concern was uncovered during the follow-up audit. It was learned that approximately 60 samples were not extracted within the specified holding time. The reasons this occurred are listed below:

- Several samples arrived at the laboratory simultaneously.
- Two personnel in the extraction laboratory had quit.
- The October 1989 San Francisco earthquake caused the laboratory shutdown of two to three days.
- Other samples were extracted ahead of BioTrol soil samples apparently because a higher priority had been placed upon these other samples.
- Newly implemented sample tracking procedures were not fully functional and caused some delay in sample extraction.

As a result of samples not being extracted within specified holding times, the laboratory initiated an additional study to assess this effect on the samples. A list of samples that missed holding times was created for the contracting QA Manager's preliminary review. The contracting QA Manager instructed laboratory personnel to re-extract several archived samples (previously extracted) with holding times nearly equal to those of samples which were not extracted within holding-time specifications. The results of these studies show the effect missed holding times had on these samples (section 6.5).

### 6.6.5 Audit of Soil Sieving Procedure for BioTrol Project

An audit was conducted by the EPA QA Contractor on October 12th on the soil sieving procedure performed by another subcontracting laboratory. A conditional rating was received for the procedure which was a non-critical measurement as specified by the QA Project Plan.

The procedure chosen for soil sieving was a combination of ASTM methods 421 and 422. This procedure was developed by the project manager and was not previously reviewed by EPA before being used.

The samples chosen were separate composites of the low and high concentration soils before treatment. One sample of each soil was sent to the laboratory. The entire sample was sieved per specifications. Except for the first sieving separation, the procedure uses wet sieving--soaking the soil in sodium hexametaphosphate (calgon solution) which has a pH between 8 and 9. Since the pKa of penta is acidic, and given the amount of time the soil is soaked in the calgon solution (16 hours) it was anticipated that most of the penta would end up in the wash solution. (This conclusion was shown to be false as indicated by results of penta in each of the soil fractions; see report.) Since PAH concentrations are relatively low, it was also believed that accurate determinations of PAH percentage in the various soil fractions would be difficult. It was anticipated that PAH concentrations would drop below analytical detection limits, except for fractions where the PAH concentration was likely to be highest.

Although the following concerns were considered minor, corrective action was warranted since many of these are standard laboratory operations which are used for all laboratory measurements.

- Daily balance calibration checks were not performed on the analytical balance in the containment laboratory.
- The pH of the calgon solution should be checked and recorded prior to usage.
- A record of reagent preparation should be recorded in the laboratory notebook.
- A record of each soil fraction weight needs to be recorded even if it is zero to avoid the appearance of a missing record.
- A daily log for the drying oven is needed.
- Percent Moisture determination should be calculated after a constant dry soil weight has been obtained.

A final issue concerned the largest sized soil fraction which appeared to be primarily "sticky clumps" of soil. The method specified use of a mortar and pestle for separation of soil clumps observed in the original sample. This was not possible since the soil had a high creosote concentration and had a gummy texture. It was decided that separation of these soil clumps could not be

achieved by mechanical means. Therefore, the soil clumps remained as a part of the largest sized soil fraction. It is likely that a high concentration of penta and PAHs are contained in this fraction due to its gummy texture and tar-like appearance. (This conclusion proved to be correct as noted in the report.)

Although several concerns resulted from last minute procedural changes, research should continue on SITE projects and additional measurements should not be discouraged. Procedures should be approved along with the QAPjP and tested prior to use, especially if they are procedures which have not been previously verified. There are provisions for pre-demonstration testing of analytical methods or potentially troublesome matrices, and such method development in this case appears to have been warranted. This approval process is not meant to prevent additional information from being gained, but should be used to insure objectives of the measurement can be obtained.

RESPONSE TO TSR DRAFT REVIEW SUMMARY OF SOIL SIEVING AUDIT

Initially this procedure was only briefly detailed in the QAPjP. Since it is a non-critical parameter, the QAPjP was approved without requiring a clearly defined procedure. This procedure was later developed by the project manager and sent to the laboratory only a few days prior to actually using the method on field samples. A blank was run first, followed by the two field samples. Once the first field sample was sieved, problems in the procedure were noted and some changes were required. The laboratory was in constant communication with the contracting QA and Project Manager regarding additional steps which needed to be taken and alternative methods which could be used.

Since these samples needed to be analyzed as quickly as possible (holding times had already been exceeded) and since no pre-validation studies had been performed, the method used was a compromise method for obtaining project objectives. It is expected only to give a gross indication of chemical partitioning for the separate soil fractions, and it is understood that the largest soil fraction also contains sticky clumps of soil which could not be separated. These clumps are not necessarily representative of larger particle sizes.

The method specified use of a mortar and pestle for separation of soil clumps observed in the original sample. This was not possible since the soil had a high creosote concentration and was a gummy texture. It was decided that separation of these soil clumps could not be achieved by mechanical means. Other types of separating processes, such as chemical separation, were discussed but not pursued due to technical considerations.

The following corrective actions were initiated in response to minor concerns previously noted:

- The balance used for percent moisture was checked to insure calibration was within project objectives.

- Preparation of the hexametaphosphate solution was properly recorded.

- Holding times were not within specifications for analysis since sieving procedures needed to be performed. Samples were sieved and analyzed as quickly as possible to insure a minimal effect in exceeding specified holding times.

## SECTION 7

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