

DCN 88-275-004-03
Radian No. 275-004-05

JUL 13 1988

RHODE ISLAND TOXICS INTEGRATION PROJECT, PHASE II:
STUDY OF AIR EMISSIONS FROM
TWO SEWAGE SLUDGE INCINERATION FACILITIES

FINAL REPORT

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June 30, 1988

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1.0 INTRODUCTION

1.1 BACKGROUND

In 1985 the Department of Environmental Management (DEM) of the State of Rhode Island initiated a Toxics Integration Project for the purpose of estimating emissions of, and locating sources of toxic pollutants in the Upper Bay Area of that state. Results from Phase I of the project identified sewage sludge incinerators as potentially significant sources of air toxics in the Upper Bay Area. The study concluded that ambient metal concentrations from sludge incineration could pose a potentially significant health risk to the exposed public.¹

As a result of the Phase I findings, the DEM contracted Radian Corporation to conduct a more refined evaluation of toxic metal emissions from two Rhode Island sewage sludge incinerators, the Cranston and Providence (Fields Point) facilities. This more detailed Phase II evaluation involved participating in a joint effort with the U.S. Environmental Protection Agency's Water Engineering Research Laboratory to perform emission tests at the Cranston facility. Further, this Phase II evaluation involved modeling of metal and organic emissions measured during the Cranston test program and modeling of site-specific emission estimates developed for the Providence incinerator.

This document describes results of the Phase II evaluation. The specific objectives of the evaluation were to:

- develop site-specific emission estimates for arsenic, beryllium, cadmium, copper, total chromium, hexavalent chromium, lead, nickel, selenium, and zinc emissions from the Providence (Fields Point) and Cranston sewage sludge incinerators;
- develop estimates of the metal concentrations in ambient air resulting from the incineration of sewage sludge using dispersion modeling techniques;

- estimate population exposure to metal emissions from each of the two incinerators; and
- develop recommendations on incinerator and control device operation that could be applied at the Rhode Island incinerators to minimize emissions of toxic air pollutants.

As work progressed, these original objectives were expanded to include compilation of organic emission data from sewage sludge incinerators, development of organic emission estimates, and modeling of organic emission estimates for the two Rhode Island incinerators.

1.2 REPORT ORGANIZATION

Section 2.0 of this report is an overview of the incineration processes and control devices used at each of the two facilities. Section 3.0 summarizes emission estimates for each of the facilities and presents emission data from literature sources for comparison. Section 4.0 summarizes the results of the risk assessment. Section 5.0 contains an engineering evaluation of the design and operating characteristics of the Cranston and Fields Point incineration and control systems and includes recommendations on how operations could be altered to minimize air toxic emissions. Section 6.0 lists the references used in preparing this document.

The supporting data for the results presented in the text of this document are included as appendices. Appendix A contains emission test results from the Cranston test program. Appendix B describes the approach used for deriving emission factors for the Fields Point incinerator. Appendix C describes the approach used for performing the dispersion modeling.

2.0 SEWAGE SLUDGE INCINERATION AND FACILITY DESCRIPTION

This section provides an overview of sewage sludge incineration and, where available, site-specific information pertaining to the two incinerators that are the focus of this study.

Each of the facilities has multiple hearth incinerators. Neither of the facilities was routinely operating their incinerators at the time this study was initiated. The Cranston plant has since begun incinerating sludge on a routine basis, and is currently incinerating approximately 15 dry tons of sludge daily. The plant operates 24 hours per day, 5 days per week.²

The Fields Point incinerator has not been operational since 1982. However, plant officials are currently considering the cost and feasibility of resuming incinerator operation. If the incinerator were operational, plant officials estimate that it would be operated continuously, resulting in the incineration of approximately 60 dry tons of sludge daily.³

This section presents available information on incinerator and control device design parameters, operation records, and sludge characteristics at each of the two facilities. Section 2.1 describes multiple hearth incinerators and a brief process description. Sections 2.2 and 2.3 contain facility descriptions and design parameters for Cranston and Fields Point, respectively.

2.1 OVERVIEW OF MULTIPLE-HEARTH INCINERATION

Each of the two Rhode Island facilities uses multiple-hearth furnaces (MHF) for sludge incineration. Figure 2-1 illustrates the overall design of an MHF. Multiple-hearth furnaces are cylindrically shaped and oriented vertically. The outer shell is constructed of steel and surrounds a series of horizontal refractory hearths. A hollow cast iron rotating shaft runs through the center of the hearths. Cooling air is introduced into the shaft by a fan located at its base. Attached to the central shaft are rabble

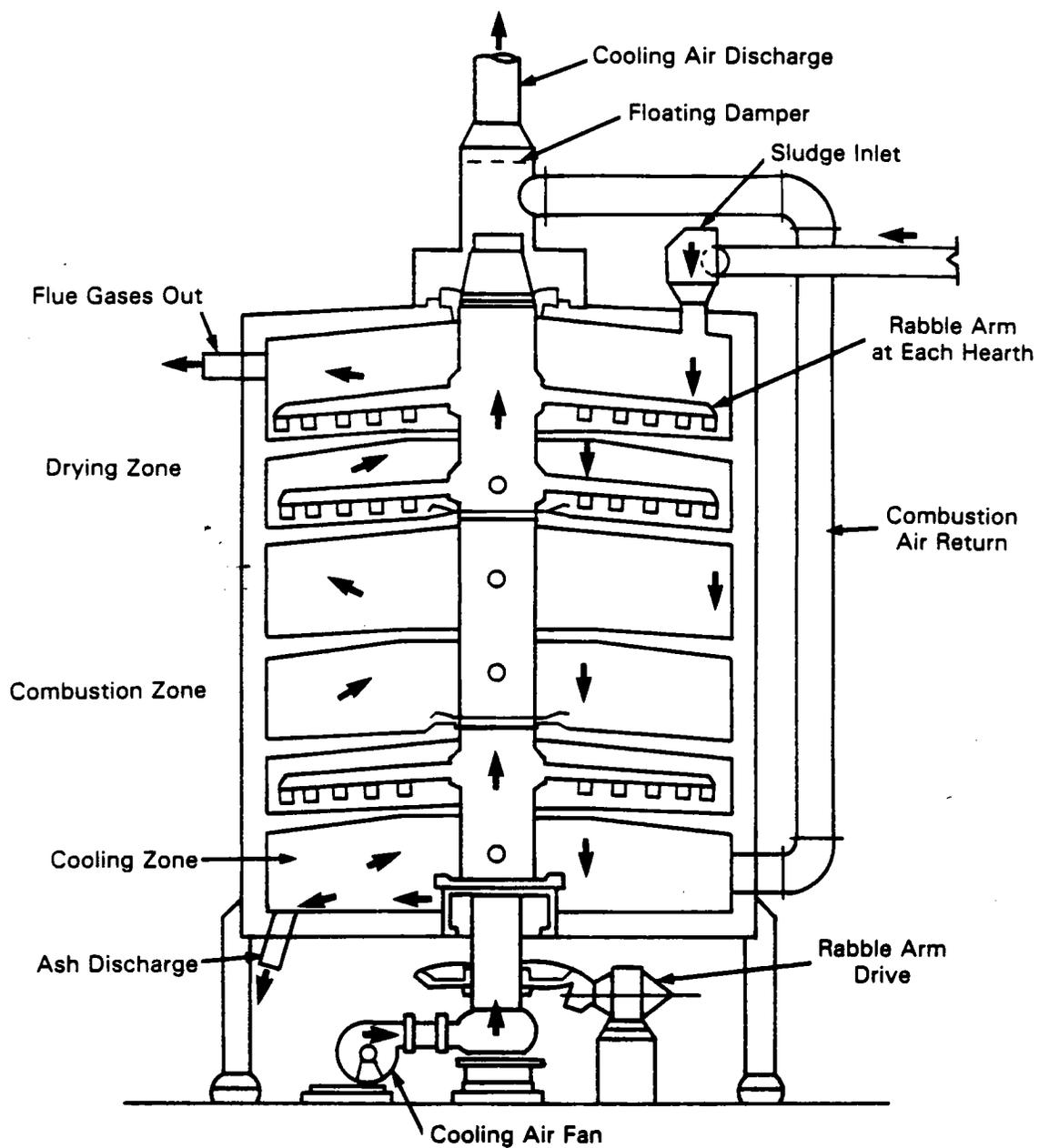


Figure 2-1. Cross-sectional view of a multiple-hearth sewage sludge incinerator.

arms, which extend above the hearths. Each rabble arm is equipped with a number of teeth, approximately 6 inches in length, and spaced about 10 inches apart. The teeth are shaped to rake the sludge in a spiral motion, alternating in direction from the outside in, to the inside out, between hearths. Either 2 or 4 rabble arms extend into each hearth. Typically, the upper and lower hearths are fitted with 4 rabble arms, while only 2 are placed within the middle hearths. Burners, which are fired using auxilliary fuel, are located in the sidewalls of the hearths.

The size of MHFs used for incineration of sewage sludge typically range from 6 hearth furnaces having an outer diameter of about 6 ft. and a total effective hearth area of 85 sq. ft., to 12 hearth, 22 ft. diameter furnaces with hearth areas of over 3000 sq. ft.⁴ Hearth loading rates range from between 7 to 12 pounds of wet sludge per hour, per square foot. This corresponds to furnace capacities of from 600 pounds of wet sludge per hour up to 18 tons per hour.

Partially dewatered sludge is fed into the periphery of the top hearth. The motion of the rabble arms rakes the sludge toward the center shaft where it drops through holes located near the edge of the hearth. In the next hearth, the sludge is raked in the opposite direction. This process is repeated in all of the subsequent hearths. The effect of the rabble motion is to break up solid material to allow better surface contact with heat and oxygen, and is arranged so that a sludge depth of about one inch is maintained in each hearth at the design sludge flow rate.

Ambient air is first ducted through the central shaft and its associated rabble arms. A portion, or all, of this air is then taken from the top of the shaft and recirculated into the lowermost hearth as preheated combustion air. Shaft cooling air which is not circulated back into the furnace is ducted into the stack downstream of the air pollution control devices. The combustion air flows upward through the drop holes in the hearths, countercurrent to the flow of the sludge, before being exhausted from the top hearth. Provisions are usually made to inject ambient air directly into one of the middle hearths as well.

From the standpoint of the overall incineration process, multiple-hearth furnaces can be divided into three zones. The upper hearths comprise the drying zone where most of the moisture in the sludge is evaporated. The temperature in the drying zone is typically between 800 and 1400°F. Combustion occurs in the middle hearths (second zone) as the temperature is increased to about 1700°F. The combustion zone can be further subdivided into the upper-middle hearths where the volatile gases and solids are burned, and the lower-middle hearths where most of the fixed carbon is combusted. The third zone, made up of the lowermost hearth(s), is the cooling zone. Hence, the ash is cooled as its heat is transferred to the incoming combustion air.

Under proper operating conditions, 50 to 100 percent excess air must be added to an MHF to ensure complete combustion of the sludge. Besides enhancing contact between fuel and oxygen in the furnace, these relatively high rates of excess air addition are necessary in order to compensate for normal variations in both the organic characteristics of the sludge feed and the rate at which it enters the incinerator. When an inadequate amount of excess air is available, only partial oxidation of the carbon will occur with a resultant increase in emissions of carbon monoxide, soot, and hydrocarbons. Too much excess air, on the other hand, can cause increased entrainment of particulates and unnecessarily high fuel consumption.

Another important parameter in the operation of a multiple-hearth sewage sludge incinerator is the rate of feed of the sludge cake. Any sudden increase or decrease in load to the furnace can severely affect the performance of the incinerator.⁵ A sharp increase in the rate of feed has been shown to lower the combustion zone in the furnace. This can subsequently lead to a decrease in temperature within the combustion zone and the potential for the fire to be extinguished. Conversely, a sudden decrease in furnace load can cause excessively high temperatures in the furnace with the attendant risk of damage to the refractories and rabble castings. The moisture content of the sludge feed must also be kept relatively constant for the same reasons.

Maintaining a uniform rate of feed into an MHF can be difficult, however. First, mechanical sludge dewatering devices are not capable of producing a sludge cake of perfectly uniform moisture content. Second, at most incineration plants, the sludge is fed directly from the treatment facility to the dewatering device, and then directly into the incinerator. Holding tanks are not usually available to independently control the rate of sludge input into the furnace. A related problem is that it may take up to an hour (or more) for the sludge to descend from the drying zone to the combustion zone in a multiple-hearth incinerator.⁶ Thus, a change in the furnace load may not be noticed by the furnace operators in time to take corrective action. Moreover, there will be an additional delay before the incinerator responds to these corrective measures and operations become stable again.

The speed at which the rabble arms are rotated can also have a critical impact on the operation of a multiple-hearth incinerator. Typically, the rotational speed can be varied between less than 1 and 3 revolutions per minute. As the speed of the rabble mechanism is increased, the rate of drying in the upper hearths is increased and the combustion zones shift upward. Combustion will also tend to take place in a greater number of hearths. Experimental data have also demonstrated that the temperature of the hottest hearth will drop as the speed of the rabble arm rotation is increased.⁷ The opposite effects are observed when the speed of the rabble motion is decreased.

However, changes in the speed of rotation of the rabble arms will initially have just the opposite effects of those described above. For example, an increase in the rabble arm speed will initially create an internal increase in the load to the combustion zone. This will cause a temporary decline of the burning zone and an overall decrease in the temperature of the lower hearths. From 1 to 3 hours are required for an MHF to stabilize after the speed of the rabble arms is changed. Because of the transient furnace instabilities caused by such changes in the speed of the rabble motion, adjustment of rabble arm speed is not an effective means of controlling the process of combustion in a multiple-hearth incinerator.⁵

Rather, the speed of the rabble movement should be set slow enough to form good furrows in the sludge, but fast enough to avoid crusting of the sludge in the upper hearths. The optimum speed is a function of the sludge moisture content and loading rate.

For optimum performance, the temperature profile within the furnace should be controlled by adjusting the firing rate of the burners. Ideally, only those burners located immediately above and below the combustion zone should be used (depending on the number of hearths, and the capacities of the available burners). This allows a greater sludge residence time in the drying zone and can decrease turbulence in the upper hearths.

Theoretically, combustion can become self-sustaining in an MHF when sludges having a heating value of at least 10,000 Btu/lb, a moisture content of less than 75 percent, and a volatile solids fraction of at least 60 to 65 percent are incinerated. However, under autogenous conditions the highest temperature in the furnace may only be about 900⁰F, which is insufficient to destroy organics.⁸ Even at minimum excess air rates, some auxilliary fuel must be burned in MHFs in order to maintain a minimum temperature of 1350⁰F for destruction of odoriferous materials.⁴

As discussed above, the operation of multiple-hearth sludge incinerators is complicated by the number of process variables, as well as by the transient nature of some of the responses observed when these variables are altered. To establish guidelines for the operation of MHF incinerators, particularly for reducing the amount of fuel consumed, a substantial amount of both theoretical and empirical research has been conducted by the Indianapolis Center for Advanced Research (ICFAR).⁹ Although the best mode of operating any incinerator is a function of numerous site-specific conditions, a number of general procedures have been established as the result of the ICFAR work. These operational guidelines include:

1. Use of shaft cooling air as combustion air;
2. Maintenance of sludge combustion on the lower burning hearths;

3. Use of only those burners located on, or immediately adjacent to, the combustion hearth(s);
4. Maintenance of rabble arm speed as slow as possible;
5. Minimization of rabble arm speed as slow as possible;
6. Maintenance of sludge loading rates at, or below, design capacity, and;
7. Maintenance of excess air at 25 to 50 percent.

Fuel savings of from 30 to 70 percent have been attained at incinerators where these procedures have been put into practice.^{5,9} Moreover, there are some indications that the operational procedures which result in reductions in fuel use also result in decreased emissions of particulates.⁹

2.2 CRANSTON

2.2.1 General Information

The Cranston wastewater facility treats an average of 10.5 million gallons of wastewater each day. The wastewater is estimated to be approximately 80 percent municipal and 20 percent industrial. Industrial contribution is primarily from jewelry and fabricated metals products; chemical and allied products; and primary metal products categories.¹ The facility is located southwest of the town of Cranston, approximately five miles from Providence, Rhode Island.

Wastewater treatment is accomplished using conventional primary and secondary treatment processes followed by chlorination. Sludge generated during the water treatment processes and ash sludge from the scrubber blowdown water are directed to sludge treatment tanks where the sludges are chemically conditioned using lime and ferric chloride. These chemical conditioning agents assist in the removal of water from the sludge solids. Further dewatering is accomplished at the Cranston facility using filter presses.

The Cranston facility has two multiple-hearth incinerators, one an 18 foot 9-inch diameter furnace with 9 hearths with a design feed rate of 8,890 lbs wet sludge/hr and the other a 14 foot 3-inch diameter furnace with 6 hearths and a design feed rate of 4,600 lbs wet sludge/hr. Only the smaller unit was operational at the time of this study. Based on discussion with plant officials, there were no plans to bring the larger incinerator on line in the near future since the small incinerator had more than sufficient capacity to handle the sludge being produced by the plant. For these reasons, this study focuses only on the smaller unit.

2.2.2 Cranston Sludge Characteristics

With the exception of data on solids and volatile solids, a limited amount of data is available to characterize the dewatered sludge produced and ultimately incinerated at the Cranston facility. Percent solids and volatile solids of the sludge filter cake are generally determined several times each day at an on-site laboratory. Table 2-1 presents a summary of percent solids and percent volatile solids data for the Cranston sludge. As seen in the table, solids content of the sludge feed is typically about 29 percent (i.e., moisture content of about 71 percent), while the percent volatile solids are in the range of 56 to 61 percent. Higher heating values of sludge samples collected during the October 1987 samples averaged about 6,500 Btu/dry lb of sludge.

Data on sludge metal content consist of information developed during the October 1987 EPA/WERL test program at the Cranston facility and grab samples collected during 1985 and 1986. These data are reported in Table 2-2.

Tables 2-3, 2-4, and 2-5 contain results from sludge analysis targeting volatile organics, dioxins, and furan species, respectively.

2.2.3 Cranston Incinerator and Pollution Control System

As discussed in subsection 2.2.1, the focus of this study focuses on the 14 foot 3-inch incinerator which is currently the only incinerator being

TABLE 2-1. GENERAL CHARACTERISTICS OF DEWATERED SLUDGE FROM THE CRANSTON WASTEWATER TREATMENT PLANT

| Parameter | Sampling Periods | | | |
|----------------------------|---------------------------|-------------------------|---------------------------|---------------------------|
| | January 1985 ^a | April 1986 ^b | October 1986 ^c | October 1987 ^d |
| Percent solids | 28.5 | 28.0 | 28.8 | 29.2 |
| Percent volatile solids | NR ^f | 61.1 | 57.6 | 56.0 |
| Oil and grease (mg/kg) | NR | 36,300 | NR | NR |
| Heating value (Btu/dry lb) | NR | NR | NR | NR |

^aResults of two sludge samples reported by R.F. Analytical Laboratories, Inc., to Joseph Mattera, Cranston WWTP, March 20, 1985. Reference 10.

^bAverage of two grab samples collected on April 21, 1986. Results reported by YWC, Inc., to Crouse Combustion System, Inc., May 16, 1986. Reference 11.

^cAverages of 119 sample analyses performed by the lab at the Cranston WWTP between October 1 and October 30, 1986. Information was obtained during a November 20, 1986, plant visit. Reference 12.

^dAverage of 17 sample analyses performed by the lab at the Cranston WWTP between September 30 and October 10, 1987. Samples were collected during the EPA/WERL emission test program. Reference 13.

^eAverage of 3 grab samples collected during the EPA/WERL emission test program. Values reported by Commercial Testing & Engineering Co. to Radian Corporation, November 6, 1987. Reference 14.

^fNot reported.

TABLE 2-2. METAL CONCENTRATION IN DEWATERED SLUDGE FROM THE CRANSTON WASTEWATER TREATMENT PLANT

| Metal | (mg of metal/kg of dry sludge) | | |
|-----------------------|--------------------------------|-------------------------|---------------------------|
| | January 1985 ^a | April 1986 ^b | October 1987 ^c |
| Arsenic | < 0.5 | 7.0 | 2.7 |
| Beryllium | NR ^d | 0.4 | 0.3 |
| Cadmium | 1.4 | 7.3 | 13.0 |
| Chromium (total) | 22.8 | 39.9 | 69.0 |
| Chromium (hexavalent) | NR | NR | NR |
| Copper | NR | 961.0 | 795.0 |
| Lead | 63.4 | 194.0 | 327.0 |
| Nickel | NR | 109.0 | 289.0 |
| Selenium | < 0.1 | < 0.5 | 1.2 |
| Zinc | NR | 611.0 | 647.0 |

^aResults of two sludge samples, reported by R.F. Analytical Laboratories, Inc. to Joseph Mattera, Cranston WWTP, March 20, 1985. Reference 10.

^bAverage of two grab samples collected on April 21, 1986. Results reported by YWC, Inc. to Crouse Combustion Systems, Inc., May 16, 1986. Reference 11.

^cAverage of 11 samples collected from incinerator feed during the Method 12 outlet testing, October 1987. Table D-5, memo from Radian Corporation to Harry Bostian, EPA/WERL. December 22, 1987. Reference 15.

^dNot reported.

TABLE 2-3. VOLATILE ORGANIC CONCENTRATION IN DEWATERED SLUDGE FROM THE CRANSTON WASTEWATER TREATMENT PLANT

| Compound | (ug/kg of dry sludge = ppb) | | |
|---------------------------|-----------------------------|-------------------------|---------------------------|
| | January 1985 ^a | April 1986 ^b | October 1987 ^c |
| Acetonitrile | NR ^d | NR | ND ^e |
| Acrylonitrile | NR | < 100 | ND |
| Benzene | < 400 | < 10 | 4 |
| Carbon tetrachloride | NR | < 10 | ND |
| Chlorobenzene | < 400 | 45 | ND |
| Chloroform | 526 | 32 | 20 |
| Chloromethane | < 400 | < 10 | NR |
| 1,2-Dichloroethane | NR | < 10 | NR |
| Trans-1,2,-Dichloroethane | NR | 763 | 22 |
| 1,1-Dichloroethene | 10,200 | < 10 | NR |
| Ethylbenzene | NR | 330 | 10 |
| Methylene chloride | < 400 | 47 | 53 |
| Pyridine | NR | NR | ND |

TABLE 2-3. (Continued)

| Compound | (ug/kg of dry sludge = ppb) | | |
|-----------------------|-----------------------------|-------------------------|---------------------------|
| | January 1985 ^a | April 1986 ^b | October 1987 ^c |
| Tetrachloroethene | 453 | 138 | 200 |
| Toluene | 5,200 | 2,080 | 294 |
| 1,1,1-Trichloroethane | 109,000 | < 10 | 41 |
| Trichloroethene | 122 | 93 | 112 |
| Vinyl chloride | ND | < 10 | ND |

^aResults of two sludge samples, reported by R.F. Analytical Laboratories, Inc. to Joseph Mattera, Cranston WWTP, March 20, 1985. Reference 10.

^bAverage of two grab samples collected on April 21, 1986. Results reported by YWC, Inc. to Crouse Combustion Systems, Inc., May 16, 1986. Reference 11.

^cAverage of 7 samples collected during the EPA/WERL emission test program, October 1987. Reference 16.

^dNot reported.

^eNo data.

TABLE 2-4. CHLORINATED DIOXIN CONCENTRATION IN DEWATERED SLUDGE FROM THE CRANSTON WASTEWATER TREATMENT PLANT^a

| Isomer | (ug/kg of dry sludge = ppb) | | | | | | Average Samples 1-6 |
|---------------------|-----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|---------------------|
| | Sample 1 10-04-87 | Sample 2 10-05-87 | Sample 3 10-06-87 | Sample 4 10-08-87 | Sample 5 10-10-87 | Sample 6 10-10-87 | |
| Total MCDD | <0.001 ^b | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Total DCDD | 0.371 | 0.195 | 1.201 | 0.412 | 0.663 | 0.398 | 0.540 |
| Total TriCDD | 0.011 | <0.001 | 0.098 | 0.019 | 0.038 | 0.014 | 0.030 |
| 2,3,7,8-TCDD | [0.002] ^c | [0.002] | [0.002] | [0.002] | [0.002] | <0.001 | 0.002 |
| Total TCDD | 0.010 | 0.007 | 0.065 | 0.029 | 0.031 | 0.014 | 0.026 |
| 1,2,3,7,8-PCDD | [0.001] | <0.001 | [0.002] | [0.001] | 0.002 | <0.001 | 0.001 |
| Total PCDD | 0.029 | 0.004 | 0.109 | [0.056] | 0.060 | 0.060 | 0.053 |
| 1,2,3,4,7,8-HxCDD | <0.001 | <0.001 | <0.001 | [0.001] | <0.001 | [0.001] | 0.000 |
| 1,2,3,6,7,8-HxCDD | 0.009 | 0.002 | 0.025 | 0.024 | 0.017 | 0.023 | 0.017 |
| 1,2,3,7,8,9-HxCDD | [0.005] | <0.001 | 0.008 | <0.001 | 0.006 | 0.006 | 0.004 |
| Total HxCDD | 0.058 | 0.010 | 0.176 | 0.142 | 0.130 | 0.146 | 0.110 |
| 1,2,3,4,6,7,8-HpCDD | 0.130 | 0.033 | 0.258 | 0.263 | 0.225 | 0.229 | 0.190 |
| Total HpCDD | 0.249 | 0.074 | 0.476 | 0.463 | 0.412 | 0.404 | 0.346 |
| OCDD | 1.000 | 0.409 | 1.941 | 2.287 | 1.955 | 2.202 | 1.632 |

^aReference 17.

^bIsomers not detected are reported as less than the minimum detection limit, and are considered as zeros in calculating averages.

^cValues in brackets represent the estimated maximum possible concentration. Such values are reported when analytical responses for the particular isomer are present but do not meet all of the quantification criteria required by the method.

TABLE 2-5. CHLORINATED FURAN CONCENTRATION IN DEWATERED SLUDGE FROM THE CRANSTON WASTEWATER TREATMENT PLANT^a

| Isomer | (ug/kg of dry sludge = ppb) | | | | | | Average Samples 1-6 |
|-------------------|-----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|---------------------|
| | Sample 1 10-04-87 | Sample 2 10-05-87 | Sample 3 10-06-87 | Sample 4 10-08-87 | Sample 5 10-10-87 | Sample 6 10-10-87 | |
| Total MCDF | [0.003] ^b | [0.003] | 0.010 | <0.001 ^c | [0.007] | 0.007 | 0.005 |
| Total DCDF | 0.086 | 0.019 | 0.315 | 0.028 | 0.138 | [0.030] | 0.103 |
| Total TriCDF | 2.391 | 1.269 | 3.726 | 5.484 | 3.397 | 2.266 | 3.089 |
| 2,3,7,8-TCDF | 0.024 | 0.008 | 0.045 | 0.041 | 0.036 | 0.042 | 0.033 |
| Total TCDF | 0.112 | 0.038 | 0.227 | 0.167 | 0.165 | 0.153 | 0.144 |
| 1,2,3,7,8-PCDF | 0.004 | [0.001] | [0.006] | [0.003] | 0.002 | 0.004 | 0.003 |
| 2,3,4,7,8-PCDF | 0.007 | 0.002 | 0.008 | [0.008] | 0.007 | 0.007 | 0.007 |
| Total PCDF | 0.063 | 0.004 | 0.061 | 0.028 | 0.041 | 0.029 | 0.038 |
| 1,2,3,4,7,8-HxCDF | 0.016 | <0.001 | [0.006] | 0.004 | [0.006] | 0.006 | 0.006 |
| 1,2,3,6,7,8-HxCDF | [0.005] | <0.001 | [0.008] | [0.002] | 0.002 | [0.003] | 0.003 |
| 2,3,4,6,7,8-HxCDF | [0.008] | <0.001 | [0.005] | 0.004 | 0.004 | [0.005] | 0.004 |
| 1,2,3,7,8,9-HxCDF | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.000 |
| Total HxCDF | 0.035 | 0.004 | 0.018 | 0.018 | 0.024 | 0.013 | 0.019 |

TABLE 2-5. (Continued)

| Isomer | (ug/kg of dry sludge = ppb) | | | | | | Average Samples 1-6 |
|---------------------|-----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|---------------------|
| | Sample 1 10-04-87 | Sample 2 10-05-87 | Sample 3 10-06-87 | Sample 4 10-08-87 | Sample 5 10-10-87 | Sample 6 10-10-87 | |
| 1,2,3,4,6,7,8-HpCDF | 0.041 | [0.004] | 0.018 | 0.014 | 0.018 | 0.016 | 0.022 |
| 1,2,3,4,7,8,9-HpCDF | [0.008] | <0.001 | <0.003 | <0.001 | <0.001 | [0.002] | 0.002 |
| Total HpCDF | 0.068 | [0.005] | 0.021 | 0.029 | 0.039 | 0.032 | 0.032 |
| OCDF | [0.048] | <0.003 | [0.049] | 0.047 | 0.058 | 0.051 | 0.042 |

^aReference 17.

^bValues in brackets represent the estimated maximum possible concentration. Such values are reported when analytical responses for the particular isomer are present but do not meet all of the quantification criteria required by the method.

^cIsomers not detected are reported as less than the minimum detection limit, and are considered as zeros in calculating averages.

used at the facility. The incinerator is a Nichols 6-hearth furnace that has been rebuilt and upgraded. A schematic diagram of the 14 foot 3-inch diameter incinerator and its pollution control system is presented in Figure 2-2. Incinerator design data are presented in Table 2-6.

Sludge is fed to the top hearth of the incinerator at a rate of about 4500 lbs/hr (as-fired basis). Rabble arms rake the sludge around the hearths and into a chute that drops the sludge to the next lower hearth. The sludge is transferred to the lower hearth at the center of the odd-numbered hearths and at the periphery of the even-numbered hearths. Hearths 1 and 2 (top hearths) are designed as drying hearths. Hearths 3 and 4 are designed to be the combustion hearths. Hearths 5 and 6 are used to cool the ash. Occasionally, some burning takes place on hearth 2 or hearth 5. There are four rabble arms for the top hearths and two rabble arms for the lower hearths.

The incinerator is also designed to burn grease and scum. These constituents are normally injected on hearth 4. An auxiliary fuel system consisting of natural gas burners is available to provide supplemental heat when necessary. There are three burners which are positioned on hearth 2, hearth 4, and hearth 6.

A shaft cooling air system is used to prevent overheating of the rabble arm shaft. Center shaft cooling air is partially recycled for use as combustion air, providing the furnace with pre-heated air. The remaining center shaft cooling air is vented to the main stack. Combustion air may be introduced through valves on hearths 2 through 6. Typically, most of the combustion air is delivered to hearth six. The furnace is designed to operate with a supply of excess air ranging from 50-150 percent.

Ash produced during the incineration process is discharged from the bottom of the furnace. The ash is transported via bucket and screw conveyors to an enclosed holding tank. The ash storage tank is periodically dumped into a truck for transport to a landfill.

Flue gas from the incinerator passes through an air pollution control system consisting of an afterburner, a precooler, a variable throat venturi, and a tray scrubber. The afterburner is a gas-fired external combustion

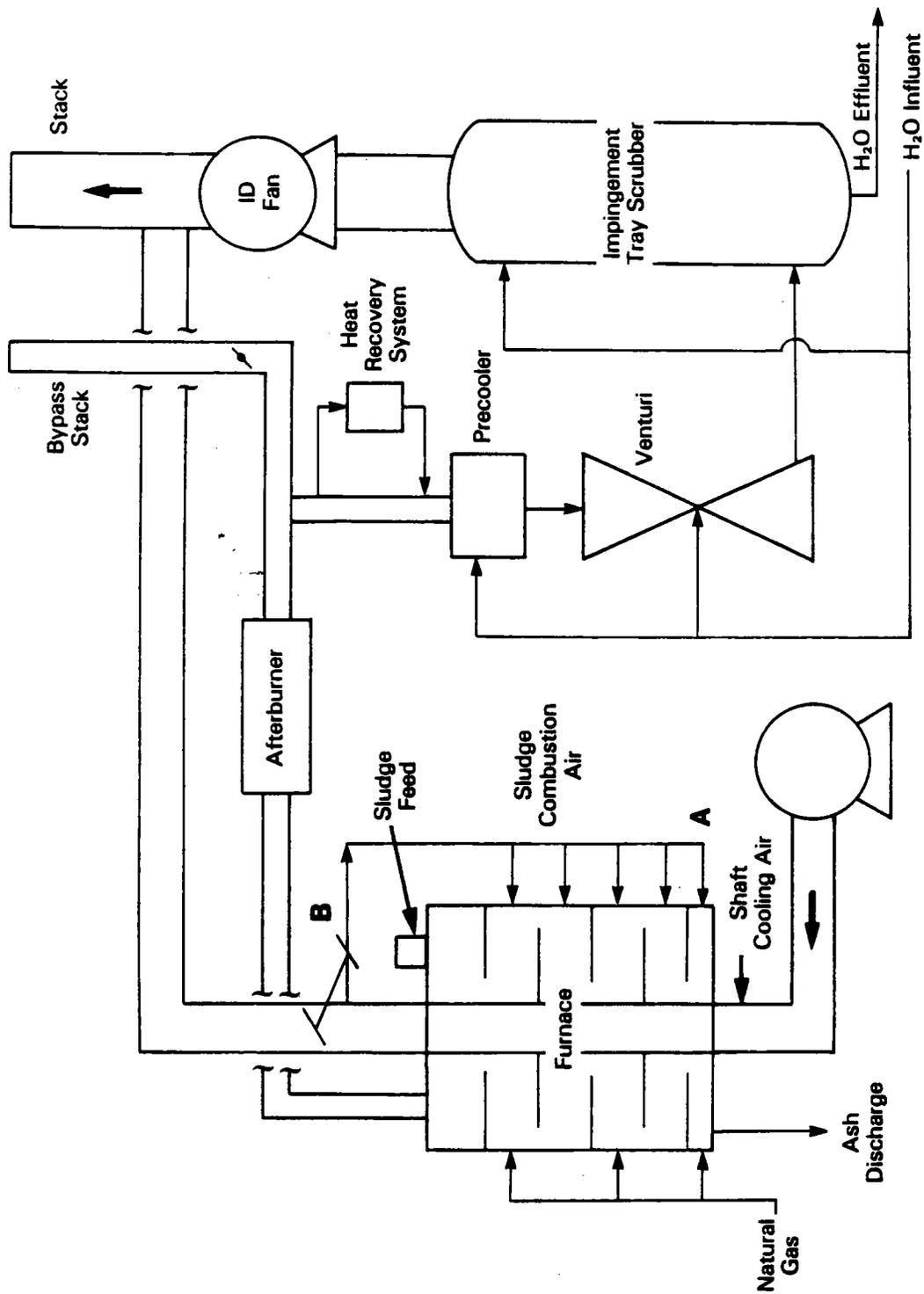


Figure 2-2. Schematic diagram of the Cranston incinerator and pollution control system.

TABLE 2-6. CRANSTON INCINERATOR AND AIR POLLUTION CONTROL SYSTEM DESIGN INFORMATION¹⁸

| Design Parameter | Value |
|---|---------------------------------|
| <u>Incinerator</u> | |
| Manufacturer | Nichols |
| Diameter | 14 foot 3-in. |
| Number of hearths | 6 |
| Recommended sludge feed rate | 4,597 lbs/hr (wet) |
| Recommended grease and scum feed | 139 lb/hr |
| Exhaust gas volume | 4,250 acfm @ 120 ⁰ F |
| Excess air | 50-150 percent |
| Oxygen: furnace exhaust | 7-10 percent |
| Auxiliary fuel | Natural gas |
| Operating Period | 24-hr/day |
| <u>Pollution Control System</u> | |
| Afterburner chamber temperature | 1400-1500 ⁰ F |
| | <u>Normal</u> <u>Maximum</u> |
| Precooler water flow | 70 gpm 100 gpm |
| Venturi | 30 gpm 50 gpm |
| Tray scrubber | 229 gpm 250 gpm |
| Gravity settler (discharge flow) | 235 gpm 250 gpm |
| Scrubber system differential pressure, in. H ₂ O | 20-38 |
| <u>Sludge Feed</u> | |
| Moisture, wt. percent | 65 |
| Solids, wt. percent | 35 |
| Combustible, percent of dry | 59.2 |
| Ash, percent of dry | 40.8 |
| Heating value, Btu/lb combustible | 9,157 |

chamber designed to destroy carbon monoxide and odorous unburned hydrocarbons in the exhaust gases. The afterburner is not used in normal operations at the Cranston facility.

The precooler reduces the temperature of the incoming flue gas and thereby reduces the volumetric flow rate. This action allows the precooler to isolate the scrubber system from the furnace so that, as the temperatures of each change, they may move relative to each other.

A circular flow channel venturi with a variable throat is used to remove larger particulate matter (soot) from the gas stream. Water is injected into the throat of the venturi and particles are removed by inertial impaction with the accelerating atomized liquid. Additionally, the venturi section further cools the gases to approximately 160°F.

The tray scrubber has four bubble cap trays for reduction of the remaining fine particulate matter in the gas stream. Particulate reduction is accomplished by physical contact with the liquid phase. The gas is cooled to an exit temperature of about 120°F. Scrubber blowdown is transferred to a gravity settler.

2.3 FIELDS POINT

2.3.1 General Information

The Fields Point wastewater facility treats an average of 52.5 million gallons of wastewater each day. The facility is owned and operated by Narraganset Bay Commission and is located southeast of Providence, Rhode Island. The Fields Point treatment plant is reported to be the largest in the New England area, serving an estimated population of 200,000.

Estimates of the influent wastewater composition indicate that 72 percent is from municipal sources while the remaining 28 percent originates from industrial sources.⁷ Industrial contribution is primarily from the jewelry and fabricated metals products; chemical and allied products; and food and kindred products source categories.¹

Wastewater treatment processes include conventional primary and secondary treatment followed by discharge to the Providence and Narragansett Bay. Sludge generated during the treatment process is chemically conditioned with lime and ferric chloride prior to dewatering using coil and cloth filters. The facility generates approximately 51 dry tons of waste sludge each day, which at the time of this study was being landfilled.

The Fields Point facility has two multiple-hearth incinerators on-site, neither of which has been used for sludge disposal since 1982. According to plant officials, only one of the incinerators (unit #2) is currently being considered for future sludge incineration. Unit #2 was originally constructed in 1959 and underwent extensive renovations in the late 1970's. Due to the renovations, the incinerator became subject to the EPA's New Source Performance Standards and subsequently the incinerator has been the subject of litigation.

Consistent with future incineration plans, this study focuses only on incinerator unit #2. Therefore the system descriptions in the following subsections and the emission estimates and modeling discussed in Sections 3.0 and 4.0 will be limited to unit #2.

2.3.2 Fields Point Sludge Characteristics

Table 2-7 summarizes general information available on dewatered sludge at the Fields Point facility. From the available measurements, percent solids average from about 22 to 30 percent with the most recent measurements being approximately 23 percent. Table 2-8 contains monthly averages of sludge metal concentrations from January 1985 to November 1986. The metals that are present in the sludge at highest concentrations are zinc and copper followed by nickel, chromium, and lead.

2.3.3 Fields Point Incinerator and Pollution Control System

As mentioned above, incinerator #2 at the Fields Point wastewater treatment facility is a renovated multiple-hearth incinerator which was originally built in 1959.

TABLE 2-7. GENERAL CHARACTERISTICS OF DEWATERED SLUDGE FROM THE
FIELDS POINT WASTEWATER TREATMENT PLANT

| Parameter | August 1982 ^a | September 1984 through September 1985 ^b | May through October 1987 ^c |
|----------------------------|--------------------------|--|---|
| Percent solids | 30.1 | 21.8 | 23.2 |
| Percent volatile solids | NR | 66.6 | NR |
| Oil and grease (mg/kg) | NR | NR | NR |
| Heating value (Btu/dry lb) | NR | NR | NR |

^aAverage of three sludge samples collected during August 10, 1982 compliance test. Reported by GCA Corp., to Narragansett Bay Water Quality Management District Commission, September 1982. Reference 19.

^bMonthly averages prepared by Daniel P. O'Connor, Assistant Director for Operations/Chief Engineer. Reference 20.

^cDischarge monitoring report data for reporting period 1/01/86 - 12/31/87, average of monthly averages. Reference 21.

NR = Not reported.

TABLE 2-8. MONTHLY AVERAGES OF TRACE METAL CONCENTRATIONS MEASURED IN FIELDS POINT SLUDGE CAKE
PPM (Wt.) IN DRY SLUDGE

| Month | Samples | Cd | Cu | Cr | Cr ⁺⁶ | Pb | Hg | Ni | Ag | Zn |
|---------------|--------------|------|---------|-------|------------------|-------|-----|-------|------|---------|
| January '85 | 3 | 10.0 | 700.0 | 0.5 | ----- | 374.8 | 3.3 | 506.7 | 28.1 | 2,491.9 |
| February '85 | 4 | 15.5 | 3,178.6 | 908.2 | ----- | 440.0 | 1.8 | 505.9 | 21.8 | 3,559.1 |
| March '85 | 6 | 12.4 | 2,191.4 | 25.2 | ----- | 374.8 | 1.9 | 418.6 | 36.7 | 3,030.0 |
| April '85 | 8 | 13.0 | 1,760.5 | 1.0 | ----- | 381.0 | 2.5 | 541.5 | 26.0 | 2,823.0 |
| May '85 | 5 | 22.3 | 1,916.4 | 5.5 | ----- | 440.5 | 4.5 | 517.3 | 24.5 | 3,833.6 |
| June '85 | 8 | 17.6 | 2,071.9 | 3.3 | ----- | 510.5 | 4.3 | 644.3 | 32.9 | 4,987.1 |
| July '85 | 4 | 16.7 | 2,471.1 | 3.9 | ----- | 488.3 | 3.3 | 428.9 | 41.7 | 4,333.3 |
| August '85 | 5 | 11.1 | 1,689.3 | 1.8 | ----- | 438.2 | 1.8 | 365.7 | 17.5 | 3,192.1 |
| April '86 | 3 | 16.5 | 2,157.0 | ----- | 680.0 | 293.0 | -- | 382.0 | 6.9 | 2,571.0 |
| May '86 | 2 | 16.0 | 1,846.0 | 661.0 | 135.0 | 246.0 | 2.0 | 320.0 | 81.0 | 2,830.0 |
| June '86 | 2 | 18.1 | 3,405.0 | 365.0 | 27.0 | 352.0 | 1.0 | 543.0 | 65.6 | 3,237.0 |
| July '86 | 2 | 21.0 | 2,907.0 | 460.0 | 33.7 | 592.0 | 1.0 | 491.0 | 87.0 | 3,847.0 |
| August '86 | 2 | 22.0 | 4,410.0 | 568.0 | 259.0 | 435.0 | 1.2 | 532.0 | 74.2 | 3,705.0 |
| September '86 | 3 | 11.1 | 5,353.0 | 746.0 | 160.0 | 372.0 | 1.3 | 894.0 | 87.7 | 6,280.0 |
| November '86 | 1 | 12.2 | 3,544.0 | 150.0 | 71.1 | 350.0 | 1.0 | 317.0 | 43.3 | 2,618.0 |
| ----- | | | | | | | | | | |
| | Average | 15.7 | 2,640.0 | 278.5 | 195.1 | 405.9 | 2.2 | 473.7 | 45.0 | 3,549.9 |
| | High | 22.3 | 5,353.0 | 908.2 | 680.0 | 592.0 | 4.5 | 894.0 | 87.7 | 6,280.0 |
| | Low | 10.0 | 700.0 | 0.5 | 27.0 | 246.0 | 1.0 | 317.0 | 6.9 | 2,491.9 |
| | 1986 Average | 16.7 | 3,374.6 | 491.7 | 195.1 | 377.1 | 1.3 | 497.0 | 63.7 | 3,584.0 |
| | High | 22.1 | 5,353.0 | 746.0 | 680.0 | 592.0 | 2.0 | 894.0 | 87.7 | 6,280.0 |
| | Low | 12.2 | 1,846.0 | 150.0 | 27.0 | 246.0 | 1.0 | 382.0 | 6.9 | 2,571.0 |

SOURCE: Reference 22.

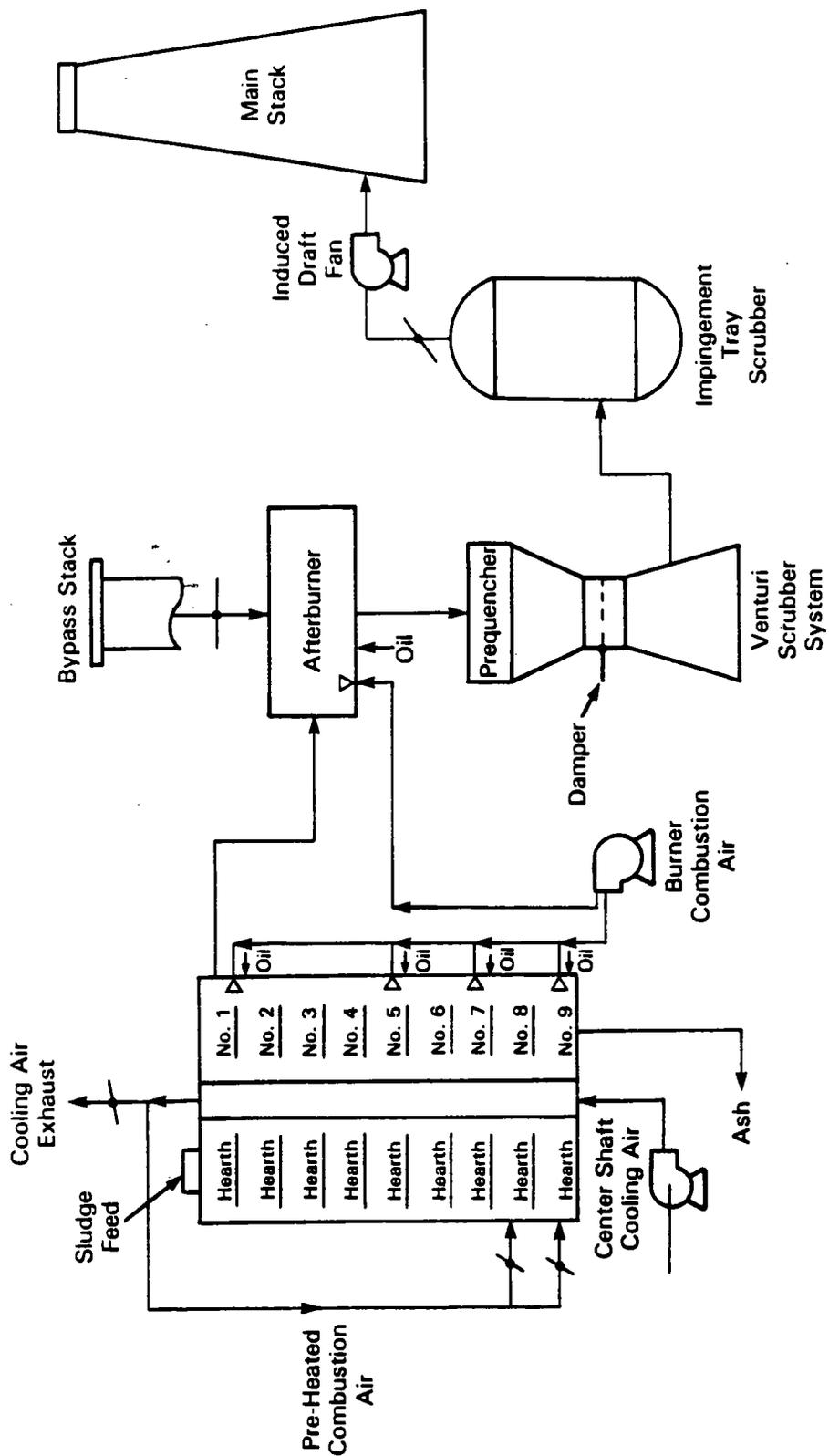
The incinerator was first owned by the City of Providence but was sold to the Narraganset Bay Commission in 1982. Renovation of the unit, which was performed by Nichols Engineering and Research Corporation, included replacement of the incinerator refractory and rabble arm system, overhauling and/or replacement of pumps, fans, and burners, replacement of gauges and controls, and installation of a venturi/impingement scrubber system. A schematic diagram of the 22 foot 3-inch diameter incinerator and its pollution control system are presented in Figure 2-3. Incinerator design data is presented in Table 2-9.

Sludge is fed to the top hearth of the incinerator at a rate of about 10 tons per hour (wet basis). Rabble arms rake the sludge around the hearths and into a chute that drops the sludge to the next lower hearth. The rabble teeth are set at an angle to the arms in such a way that when the center shaft and arms rotate, the teeth will rake the sludge toward the center shaft on the even-numbered hearths and away from the center shaft on the odd-numbered hearths. Therefore, the sludge is transferred to the lower hearth at the center of the odd-numbered hearths and at the periphery of the even-numbered hearths.

The upper part of the furnace is the drying zone. The number of hearths required for drying the sludge is dependent upon the sludge feed rate, moisture content, and percent combustibles. Generally, the drying zone occupies hearths 1 through 4. Hearths 5 and 6 are the zones in which combustion takes place while the remaining hearths (7-9) are the zones in which the ash is cooled prior to being discharged into the ash system.

An auxiliary fuel system consisting of oil burners is available to provide auxiliary heat to support sludge combustion when necessary. In addition, the auxiliary system provides heat for incinerator warm-up during start-up periods and heat to maintain stand-by temperatures during periods in which sludge feed is interrupted. Two burners are located on hearth number 1, and four burners are located on each of hearths 5, 7, and 9.

A shaft cooling air system is used to prevent overheating of the rabble arm shaft. Center shaft cooling air increases in temperature from ambient to about 400⁰F. A portion of the cooling air may be recycled to hearths 7



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Figure 2-3. Schematic Diagram of the Fields Point Incinerator and Pollution Control System

TABLE 2-9. FIELDS POINT INCINERATOR OPERATING AND DESIGN INFORMATION

| Design Parameter | Value |
|--|-----------------------------|
| <u>Incinerator</u> | |
| Manufacturer | Nichols |
| Diameter | 22 foot 3-inch |
| Number of hearths | 9 |
| Recommended sludge feed rate (maximum) | 10 tons/hr (wet) |
| Exhaust gas volume | 89,537 acfm |
| Excess air | 50-125 percent |
| Oxygen furnace exhaust | 10-12 percent |
| Auxiliary fuel | No. 2 fuel oil |
| Hearth temperatures | |
| Hearth 1 | 700 to 1000 ^o F |
| Hearth 2 | 700 to 1200 ^o F |
| Hearth 3 | 1000 to 1300 ^o F |
| Hearth 4 | 1200 to 1600 ^o F |
| Hearth 5 | 1200 to 1600 ^o F |
| Hearth 6 | 1000 to 1400 ^o F |
| Hearth 7 | 800 to 1000 ^o F |
| Hearth 8 | Below 800 ^o F |
| Hearth 9 | Below 500 ^o F |
| <u>Sludge Feed</u> | |
| Moisture, wt. percent | 72 to 78 percent |
| Solids, wt. percent | 22 to 28 percent |
| Volatile solids, percent of dry | 55 to 75 percent |

SOURCE: Reference 23.

and 9 for use as combustion air by means of a manually operated damper. The remainder of the cooling air is exhausted through the cooling air exhaust stack.

In addition to recycled shaft cooling air, combustion air is introduced through slightly open doors, peep holes, auxiliary burners, etc., by the suction created by the induced draft fan. The furnace is designed to operate with a supply of excess air ranging from 50 to 125 percent.

Flue gas from the incinerator passes through an air pollution control system consisting of an afterburner, a quencher section, a variable throat venturi, and a tray scrubber. Air pollution control system design data are presented in Table 2-10. The afterburner is an oil-fired external combustion chamber designed to destroy carbon monoxide and unburned hydrocarbon.

The first section of the scrubbing system is the quenching section. As the gases flow downward through the quencher section, the gas stream is washed by low pressure water sprays to entrap heavier particulate. Further, sufficient water flow is introduced to the gas stream to reduce the temperature and thereby reduce the volumetric flow rate. The gas stream velocity in the quencher is controlled by a manually operated variable throat venturi. The restriction imposed on the gas flow by the venturi causes the gas velocity to increase. The water droplets scrub the particles from the gas stream. Flue gases then enter the impingement scrubber section which serves to further scrub and cool the exhaust stream. The impingement section consists of two trays for reduction of fine particulate matter. The perforated tray sheets are mounted directly above one another with water supplied through two inlet nozzles located above the top tray plate. The function of the perforated sheet is to break up the gas stream into high velocity jets. With the flow of water across the tray, each jet is then transformed into bubbles, which pass through the remaining tray and finally through a mist eliminator to remove carry over prior to discharging the gases through the scrubber outlet stack.

TABLE 2-10. FIELDS POINT AIR POLLUTION CONTROL SYSTEM DESIGN DATA

| | |
|---|--------------------------------------|
| Quencher venturi gas volume | 89,537 acfm |
| Quencher venturi inlet gas temperature | 1400 ⁰ F |
| Inlet pressure | - 2" w.c. |
| Quencher pressure drop | 1 to 2" w.c. |
| Quencher venturi pressure drop | 23" w.c. |
| Separator pressure drop | 8" w.c. |
| Quencher liquid rate | 220 gpm @ 15 psig, 75 ⁰ F |
| Venturi liquid rate | 400 gpm @ 3 psig, 75 ⁰ F |
| Cooler liquid rate | 1200 gpm @ 3 psig, 75 ⁰ F |
| Outlet gas volume @ .32" w.c. | 24,737 acfm |
| Outlet gas temperature | 110 ⁰ F |
| Total maximum scrubber system pressure drop | 32" w.c. |

SOURCE: Reference 23.

3.0 EMISSION FACTOR ESTIMATES

This section presents emission factor estimates which are used as the basis for dispersion modeling. In addition to emission factor estimates, this section briefly describes the approach used to derive the estimates and compares the emission estimates derived for each of the two facilities with emissions data from the literature.

As a preface to this section, it is important that readers of this document understand certain limitations associated with all emission factor estimate approaches. No emission factor estimation approach is perfect. All approaches are subject to error and are at best educated guesses. Even emission factor estimates based on stack gas measurements are not perfect, since the values only provide a "snapshot" of the emissions during a particular time frame, on a particular day. However, derivation of emission factors from actual emission measurements is the most accurate and reliable approach. Emission factor estimates for the Cranston facility were derived based on stack measurements and are therefore judged to be of the highest quality.

Most often, emission factors are derived without site-specific emission measurements. This approach relies heavily on literature sources and other general information. Such a generalized approach provides a rough order of magnitude type emission factor and does not necessarily reflect site-specific considerations such as process and control device operations. The approach used for estimating emission factors for the Fields Point facility into this more generalized category of emission factor development approaches. As discussed in Appendix B, to the extent possible, site-specific information was used in the development of emission factors for the Fields Point facility.

In summary, the emission factor estimates for the two facilities differ in their relative accuracies. Emission factors for Cranston, which were derived based on stack measurements, are judged to be of highest quality and

judged to be fairly accurate estimates of actual plant performance. Emission factors derived for Fields Point are best ball park estimates of plant performance and are not judged to be of the same accuracy as the Cranston estimates.

Emission factor estimates are organized into five categories. These categories include trace metals, volatile organics, semivolatile organics, PCBs and pesticides, and chlorinated dioxins and furans. Each of these emission categories are discussed in the following subsections.

3.1 TRACE METAL EMISSIONS

Table 3-1 presents trace metal emission estimates for both Cranston and Fields Point facilities. Emissions are expressed on both an emission rate (g/hr) and emission factor basis (mg/kg).

Trace metal emission estimates for Cranston are based on measurements performed during an October 1987 test program. Trace metal emission rates shown in Table 3-1 reflect controlled metal emissions during periods of normal or typical furnace and air pollution control system operation. During the test program, three metals of interest (beryllium, selenium, and hexavalent chromium) were either not detected or not quantified due to analytical interferences. Beryllium and selenium emission rates were below the analytical detection limits of 1 mg/hr. Hexavalent chromium emission rates were not quantified due to unacceptable blank values. Hexavalent chromium emissions were estimated by assuming that the ratio of hexavalent to total chromium in the stack exhaust gas is in the same proportion as the incoming sludge feed. Based on measurements during the October 1987 test program, this ratio of hexavalent to total chromium in the Cranston sludge is approximately 0.07 to 1.

Metal emission estimates for the Fields Point facility were developed based on both site-specific data and information from the literature. Site-specific data considered in the estimation approach included information on the facility's sludge characteristics, furnace and air pollution equipment, and operational practices.

TABLE 3-1. TRACE METAL EMISSION VALUES USED AS INPUTS TO DISPERSION MODELING

| Metal | Cranston ^a | | Fields Point ^b | |
|---|-----------------------|---------------------|---------------------------|--------------------|
| | g/hr | mg/kg | g/hr | mg/kg |
| Arsenic (As) | 0.025 | 0.04 | 0.091 ^e | 0.04 ^e |
| Beryllium (Be) | <0.001 ^c | <0.002 ^c | 0.005 ^e | 0.002 ^e |
| Cadmium (Cd) | 1.57 | 2.72 | 1.88 | 0.83 |
| Copper (Cu) | 3.13 | 5.44 | 139.87 | 61.62 |
| Chromium (Cr) | 2.81 | 4.89 | 22.37 | 9.85 |
| Hexavalent Chromium (Cr ⁺⁶) | 0.20 ^d | 0.35 ^d | 5.58 ^d | 2.46 ^d |
| Lead (Pb) | 17.94 | 31.20 | 24.78 | 10.92 |
| Nickel (Ni) | 0.25 | 0.44 | 21.85 | 9.63 |
| Selenium (Se) | <0.001 ^c | <0.002 ^c | 0.005 ^e | 0.002 ^e |
| Zinc (Zn) | 27.13 | 47.20 | 201.33 | 88.69 |

^aTrace metal emission values for Cranston are based on stack gas measurements, except where noted.

^bTrace metal emission values for Fields Point are estimated based on known sludge characteristics, control device operating conditions, engineering judgment, and literature sources, except where noted. A detailed description of the emission estimate procedure is included in Appendix B.

^cBeryllium and selenium were not detected. Values presented represent the method detection limit and are therefore higher than the actual emission rate.

^dHexavalent chromium emissions were estimated by assuming that the ratio of hexavalent to total chromium in the stack exhaust is in the same proportion as the incoming sludge feed.

^eThese trace metal emission estimates for Fields Point are based solely on the emission factor derived for the Cranston plant. There were insufficient literature or plant-specific data to support other emission estimate approaches.

Appendix B of this document describes in detail the model which was developed as part of this study used for estimating metal emissions from the Fields Point incinerator. With the exception of arsenic, beryllium, selenium, and hexavalent chromium, emission factors for each of the metals of interest were derived using the model. Arsenic, beryllium, and selenium were derived from available literature sources as described for Cranston. Hexavalent chromium emissions were estimated using the same approach as described for the Cranston facility. The ratio of hexavalent to total chromium in the Fields Point sludge is approximately 0.25 to 1.

In Table 3-1, note that on an emission rate basis (g/hr) Fields Point emissions are typically much higher than Cranston. This is due to the higher volumetric flowrate at Fields Point which is a result of the larger furnace and higher sludge feed rate.

Table 3-2 shows a comparison between trace metal emission factors estimated for the Cranston and Fields Point facility, and the range of measured emission factors from literature sources. As seen in the table, emission factors (mg metal emitted per kg of sludge burned) for the Cranston facility are well within the range of those factors from literature sources. When emission factors for the Fields Point facility are expressed on a percentage of metal feed basis, as seen in Table 3-3, each of these emission factors generally fall within the range of literature sources.

Table 3-4 summarizes trace metal emission from literature sources expressed as mg of metal emitted per kg of dry sludge burned. Table 3-5 contains a summary of trace metal emissions from literature sources expressed as percent of sludge metal feed (g metal emitted per g of metal fed x 100).

3.2 VOLATILE ORGANIC EMISSIONS

Table 3-6 presents volatile organic emission estimates for both Cranston and Fields Point facilities. Emissions are expressed on both an emission rate (g/hr) and emission factor (mg/kg) basis.

TABLE 3-2. COMPARISON OF TRACE METAL EMISSION FACTORS FOR CRANSTON, FIELDS POINT AND LITERATURE SOURCES
(mg of metal emitted per kg of dry sludge burned)

| Metal | Data from Literature Sources | | | Emission Factors Used in Dispersion Modeling (mg/kg) | |
|--------------------|------------------------------|-----------------|-----------------|--|---------------------------|
| | Low mg/kg | High mg/kg | Average mg/kg | Cranston ^a | Fields Point ^b |
| Arsenic (As) | 0.02 | 0.90 | 0.20 | 0.04 | 0.04 ^d |
| Beryllium (Be) | <0.001 | <0.004 | <0.002 | <0.002 ^c | 0.002 ^d |
| Cadmium (Cd) | 0.26 | 7.87 | 2.60 | 2.72 | 0.83 |
| Copper (Cu) | 0.31 | 27.06 | 9.11 | 5.44 | 61.62 |
| Chromium (Cr) | 0.19 | 16.10 | 3.37 | 4.89 | 9.85 |
| Chromium Hx (Cr+6) | NA ^f | NA ^f | NA ^f | 0.35 ^e | 2.46 ^b |
| Lead (Pb) | 0.45 | 111.69 | 31.76 | 31.2 | 10.92 |
| Nickel (Ni) | 0.10 | 5.88 | 2.13 | 0.44 | 9.63 |
| Selenium (Se) | 0.26 | 5.13 | 1.39 | <0.002 ^c | 0.002 ^d |
| Zinc (Zn) | 1.44 | 79.77 | 28.81 | 47.20 | 88.17 |

^a Trace metal emission values for Cranston are based on stack gas measurements except where noted.

^b Fields Point emission factors are based on the model discussed in Appendix B, except where noted. Average case using time-weighted scrubber operation data.

^c Beryllium and selenium were not detected. Values presented represent the method detection limit and are therefore higher than actual emission rates.

^d These trace metal emission estimates for Fields Point are based solely on the emission factor derived for the Cranston plant. There were insufficient literature or plant-specific data to support other emission estimate approaches.

^e Estimated based on total chromium emission factor and ratio of hexavalent to total chromium in sludge feed.

^f NA = Not available.

TABLE 3-3. COMPARISON OF TRACE METAL EMISSION FACTORS FOR CRANSTON, FIELDS POINT AND LITERATURE SOURCES EXPRESSED AS PERCENTAGE OF METAL FEED
 ([g metal emitted/g metal fed] x 100)

| Metal | Data from Literature Sources | | | Cranston ^a | Fields Point ^b |
|--------------------|------------------------------|-----------------|-----------------|-----------------------|---------------------------|
| | Low | High | Average | | |
| Arsenic (As) | 0.03 | 7.50 | 2.58 | 1.61 | NA ^C |
| Beryllium (Be) | NA ^C | NA ^C | NA ^C | NA ^C | NA ^C |
| Cadmium (Cd) | 0.18 | 51.17 | 12.21 | 20.96 | 4.96 |
| Copper (Cu) | 0.02 | 15.4 | 2.37 | 0.69 | 1.78 |
| Chromium (Cr) | 0.03 | 7.09 | 1.06 | 7.09 | 1.82 |
| Chromium Hx (Cr+6) | NA ^C | NA ^C | NA ^C | NA ^C | NA ^C |
| Lead (Pb) | 0.13 | 43.00 | 8.96 | 9.54 | 2.89 |
| Nickel (Ni) | 0.02 | 6.85 | 1.45 | NA ^C | 1.81 |
| Selenium (Se) | 0.10 | 1.73 | 0.99 | NA ^C | NA ^C |
| Zinc (Zn) | 0.06 | 9.85 | 2.35 | 7.29 | 2.35 |

^aThese factors are based on emission factors presented in Table 3-1, divided by measured sludge metal contents. See Table 3-1, for additional footnotes pertaining to derivation of factors for specific metals.

^bFields Point emission factors are based on the model discussed in Appendix B, except where noted. Average case using time-weighted scrubber operation data.

^CNA = Not available.

TABLE 3-4. SUMMARY OF TRACE METAL EMISSIONS FROM SLUDGE INCINERATORS
(mg metal emitted/kg of dry sludge burned)

| Incinerator | Furnace Type ^a | Control ^b Technology | Reference | As | Be | Cd | Cu | Cr | Pb | Ni | Se | Zn | |
|-------------|---------------------------|---------------------------------|-----------|---------------------|--------|--------------------|-------|-------|--------|--------|------|-------|-------|
| MERL A | MHF | I | 24 | 0.08 | NR | 7.18 | NR | 2.73 | 53.36 | 2.29 | NR | 11.98 | |
| MERL B | MHF | I | 24 | 0.24 | NR | 3.28 | NR | 4.24 | 88.27 | 3.06 | NR | 70.98 | |
| MERL C | MHF | I | 24 | 12.79 ^c | NR | 63.46 ^c | NR | 4.78 | 32.71 | 2.37 | NR | 79.77 | |
| MERL E | MHF | V & I | 24 | 0.02 | NR | 0.72 | NR | 0.19 | 33.61 | 0.13 | NR | 15.34 | |
| MERL F | MHF | V & I | 24 | 0.06 | NR | 0.26 | NR | 0.51 | 7.20 | 0.10 | NR | 3.30 | |
| MERL G | FB | V & I | 24 | 0.08 | NR | 1.81 | NR | 0.36 | 111.69 | 78.06 | NR | 1.44 | |
| WERL 1 | MHF | I | 25 | 0.12 | <0.004 | 0.69 | NR | 0.37 | 35.93 | 0.23 | NR | NR | |
| WERL 2 | MHF | V & I | 26 | 0.41 | <0.001 | 1.94 | NR | 0.53 | 4.57 | 1.63 | NR | NR | |
| WERL 3 | FB | V & I | 27 | 0.03 | <0.001 | 0.27 | NR | 0.71 | 0.45 | 5.88 | NR | NR | |
| CRANSTON | MHF | V & I | 28 | 0.04 | <0.001 | 2.72 | 5.44 | 4.89 | 31.19 | 0.44 | NR | 47.19 | |
| ESRL O | MHF | I | 29 | NR | NR | 1.51 | NR | 3.53 | 18.67 | NR | NR | 29.54 | |
| ESRL P | MHF | I | 29 | NR | NR | 1.20 | 27.06 | 16.1 | 38.87 | [-] | 0.69 | 61.31 | |
| ESRL Q | FB | I | 29 | NR | NR | 0.15 | 0.31 | 0.31 | 2.53 | 4.11 | 0.40 | 1.92 | |
| ESRL R | MHF | C | 29 | NR | NR | 31.22 ^c | 8.68 | 3.72 | 35.39 | [-] | 0.45 | 30.32 | |
| WERL A | MHF | V & I | 30 | 0.90 | NR | 7.87 | 10.95 | 9.90 | 10.18 | 3.91 | 5.13 | 14.0 | |
| WERL B | MHF | C + V & I | 31 | 0.20 | NR | 6.83 | 2.24 | 1.03 | 3.60 | 1.39 | 0.26 | 7.44 | |
| | | | | Average | 0.20 | <0.002 | 2.60 | 9.11 | 3.37 | 31.76 | 2.13 | 1.39 | 28.81 |
| | | | | No. of Observations | 11 | 4 | 14 | 6 | 16 | 16 | 12 | 5 | 13 |
| | | | | Standard Deviation | 0.26 | 0.002 | 2.71 | -- | 4.29 | 31.35 | 1.85 | -- | 27.44 |
| | | | | High | 0.90 | 0.004 | 7.87 | 27.06 | 16.10 | 111.69 | 5.88 | 5.13 | 79.77 |
| | | | | Low | 0.02 | 0.001 | 0.26 | 0.31 | 0.19 | 0.45 | 0.10 | 0.26 | 1.44 |

^aMHF = Multiple-hearth furnace; FB = Fluidized-bed furnace.

^bI = Impingement tray scrubber, V & I = Venturi and Impingement tray scrubber, C = Cyclone.

^cExcluded from average.

NR = Not reported.

TABLE 3-5. SUMMARY OF TRACE METAL EMISSIONS FROM SLUDGE INCINERATORS EXPRESSED AS PERCENT OF SLUDGE METAL FEED IN CONTROLLED OFFGASES
(lg metal emitted/g metal fed) x 100)

| Incinerator | Furnace Type ^a | Control ^b Technology | Reference | As | Be | Cd | Cu | Cr | Pb | Ni | Se | Zn | |
|-------------|---------------------------|---------------------------------|-----------|---------------------|------|--------------------|-------|------|-------|--------------------|-------|------|------|
| MERL A | MHF | I | 24 | NR | NR | 16.70 | 0.41 | 0.16 | 1.99 | 0.41 | NR | 0.4 | |
| MERL B | MHF | I | 24 | NR | NR | 1.09 | 4.83 | 0.28 | 15.96 | 2.41 | NR | 2.6 | |
| MERL C | MHF | I | 24 | NR | NR | 51.17 ^v | 0.80 | 0.47 | 4.54 | 0.18 | NR | 1.9 | |
| MERL E | MHF | V & I | 24 | NR | NR | 5.96 | 0.07 | 0.04 | 2.92 | 0.02 | NR | 0.3 | |
| MERL F | MHF | V & I | 24 | NR | NR | 2.37 | 0.38 | 0.22 | 3.38 | 0.08 | NR | 0. | |
| MERL G | FB | V & I | 24 | NR | NR | 10.66 | 0.02 | 0.03 | 26.28 | 52.04 ^c | NR | 0. | |
| WERL 1 | MHF | I | 25 | 6.10 | NR | 31.00 | NR | 0.20 | 43.00 | 1.3 | NR | NR | |
| WERL 2 | MHF | V & I | 26 | 7.50 | 0.20 | 22.00 | NR | 0.60 | 4.70 | 1.9 | NR | NR | |
| WERL 3 | FB | V & I | 27 | 0.11 | NR | 4.10 | NR | 0.25 | 0.13 | 0.49 | NR | NR | |
| CRANSTON | MHF | V & I | 28 | 1.61 | NR | 20.96 | 0.69 | 7.09 | 9.54 | NR | NR | 7. | |
| ESRL O | MHF | I | 29 | NR | NR | 7.55 | NR | 1.60 | 5.49 | NR | NR | 9. | |
| ESRL P | MHF | I | 29 | NR | NR | 3.00 | 3.61 | 3.34 | 8.10 | NR | <1.73 | 5. | |
| ESRL Q | FB | I | 29 | NR | NR | 0.18 | 0.12 | 0.14 | 0.43 | 6.85 | <1.0 | 0. | |
| ESRL R | MHF | C | 29 | NR | NR | 100 ^c | 15.4 | 0.98 | 15.39 | NR | 1.13 | 2. | |
| WERL A | MHF | V & I | 30 | 0.12 | NR | 3.35 | 2.06 | 1.28 | 1.03 | 1.51 | NR | 0. | |
| WERL B | MHF | C + V & I | 31 | 0.03 | NR | 3.01 | 0.05 | 0.28 | 0.53 | 0.84 | 0.10 | 0. | |
| | | | | Average | 2.58 | 0.20 | 12.21 | 2.37 | 1.06 | 8.96 | 1.45 | 0.99 | 2.35 |
| | | | | No. of Observations | 6 | 1 | 15 | 12 | 16 | 16 | 11 | 4 | 13 |
| | | | | Standard Deviation | 3.35 | -- | 14.16 | 4.39 | 1.82 | 11.55 | 1.95 | 0.67 | 3.20 |
| | | | | High | 7.50 | -- | 51.17 | 15.4 | 7.09 | 43.00 | 6.85 | 1.73 | 9.85 |
| | | | | Low | 0.03 | -- | 0.18 | 0.02 | 0.03 | 0.13 | 0.02 | 0.10 | 0.06 |

^a MHF = Multiple-hearth furnace; FB = Fluidized-bed furnace.

^b I = Impingement tray scrubber, V & I = Venturi and Impingement tray scrubber, C = Cyclone.

^c Excluded from average.

NR = Not reported.

TABLE 3-6. VOLATILE ORGANIC EMISSION VALUES USED AS INPUTS FOR DISPERSION MODELING

| Compound | Cranston ^a | | Fields Point ^a | |
|--------------------------|-----------------------|-------------------|---------------------------|-------------------|
| | mg/hr | mg/kg | mg/hr | mg/kg |
| Acetonitrile | 6,158 | 10.71 | 24,312 | 10.71 |
| Acrylonitrile | 20,459 | 35.58 | 80,767 | 35.58 |
| Benzene | 4,169 | 7.25 | 17,593 | 7.25 |
| Bromodichloromethane | 851 ^b | 1.48 ^b | 3,360 ^b | 1.48 ^b |
| Bromomethane | 29 ^b | 0.05 ^b | 114 ^b | 0.05 ^b |
| 2-Butanone (MEK) | 5,238 | 9.11 | 20,680 | 9.11 |
| Carbon Tetrachloride | 12 | 0.02 | 45 | 0.02 |
| Chlorobenzene | 506 | 0.88 | 1,998 | 0.88 |
| Chloroethane | 460 ^b | 0.80 ^b | 1,816 ^b | 0.80 ^b |
| Chloromethane | 2,967 | 5.16 ^b | 11,713 | 5.16 |
| Chloroform | 236 | 0.41 | 931 | 0.41 |
| 1,1-Dichloroethane | 132 ^b | 0.23 ^b | 522 ^b | 0.23 ^b |
| 1,2-Dichloroethane | 12 | 0.02 | 45 | 0.02 |
| trans-1,2 Dichloroethane | 29 | 0.05 | 114 | 0.05 |
| 1,1-Dichloroethene | 144 ^b | 0.25 ^b | 568 ^b | 0.25 ^b |
| Ethylbenzene | 1,006 | 1.75 | 3,973 | 1.75 |
| Methylene Chloride | 1,392 | 2.42 | 5,493 | 2.42 |
| Tetrachloroethene | 845 | 1.47 | 3,337 | 1.47 |
| Toluene | 3,927 | 6.83 | 15,504 | 6.83 |
| 1,1,1-Trichloroethane | 1,047 | 1.82 | 4,131 | 1.82 |
| Trichloroethene | 1,432 | 2.49 | 5,652 | 2.49 |
| Vinyl Chloride | 960 | 1.67 | 3,791 | 1.67 |
| Xylene | 2,323 ^b | 4.04 ^b | 9,171 ^b | 4.04 ^b |

^a Volatile organic emission factors are based on stack gas measurements at Cranston, except where noted. No emission measurements were performed at Fields Point.

^b Emission factor for this compound is based on literature sources.

Volatile organic emission estimates for Cranston are based on measurements performed during an October 1987 test program. Volatile organic emission rates shown in Table 3-6 reflect controlled emissions during periods of normal or typical furnace and air pollution control systems operation. Emission estimates for those organics not quantified in the Cranston test program were derived based on available literature. Table 3-6 denotes and distinguishes between those emission factor estimates based on Cranston measurements and literature sources.

Volatile organic emission estimates for the Fields Point facility were based on emission (mg per kg of dry sludge) factors derived from the Cranston test program. Such an approach provides only an order of magnitude type estimate for Fields Point. No attempt was made to manipulate or "adjust" the Cranston values to derive different emission factors for Fields Point. Attempts to adjust emission values would imply that the relationship between specific operating parameters and conditions and organic emissions is quantitatively known. There is no justification for assuming that the organic emission factors should differ significantly between the two plants. Table 3-7 a compares emission factors estimated for the Cranston and Fields Point facilities with the range of measured emission factors from literature sources. Table 3-8 contains a summary of volatile organic emissions from sludge incinerators as available from the literature.

3.3 SEMIVOLATILE ORGANIC EMISSIONS

Table 3-9 presents semivolatile organic emission estimates for the Cranston and Fields Point facilities. Since semivolatile organics were not measured in controlled off-gases during the Cranston test program, and no data are available for Fields Point, the data presented are simply averages from literature sources. Note that semivolatiles are divided into two categories, acid and base compounds. Of the semivolatile acid category, only two compounds have been quantified during incinerator tests. These are 2-nitrophenol and phenol. Of the semivolatile base category, four compounds have been quantified. These include three dichlorobenzene isomers and bis(2-ethylhexyl)phthalate. For the purpose of deriving order of

TABLE 3-7. VOLATILE ORGANIC EMISSION ESTIMATES FOR CRANSTON AND FIELDS POINT SEWAGE SLUDGE INCINERATORS
(mg emitted/dry kg of sludge burned)

| Compound | Literature Sources | | Cranston ^a | Fields Point ^b |
|--------------------------|--------------------|-------------------|-----------------------|---------------------------|
| | Range | Average | | |
| Acetonitrile | 0.79 - 10.71 | 5.75 | 10.71 | 10.71 |
| Acrylonitrile | <0.03 - 35.58 | 13.05 | 35.58 | 35.58 |
| Benzene | 0.18 - 25.34 | 8.55 ^c | 7.25 ^c | 7.25 ^d |
| Bromodichloromethane | NA | 1.48 ^c | 1.48 ^d | 1.48 ^d |
| Bromomethane | NA | 0.05 ^c | 0.05 ^d | 0.05 ^d |
| 2-Butanone (MEK) | 0.05 - 9.11 | 5.38 | 9.11 | 9.11 |
| Carbon Tetrachloride | <0.01 - 0.16 | 0.03 | 0.02 | 0.02 |
| Chlorobenzene | <0.01 - 3.07 | 1.01 ^c | 0.88 ^d | 0.88 ^d |
| Chloroethane | NA | 0.80 ^c | 0.80 ^d | 0.80 ^d |
| Chloromethane | NA | 5.16 ^c | 5.16 ^d | 5.16 ^d |
| Chloroform | 0.41 - 8.50 | 3.65 ^c | 0.41 ^d | 0.41 ^d |
| 1,1-Dichloroethane | NA | 0.23 ^c | 0.23 ^d | 0.23 ^d |
| 1,2-Dichloroethane | <0.01 - 0.04 | 0.02 | 0.02 | 0.02 |
| trans-1,2-Dichloroethane | <0.01 - 5.20 | 0.05 ^c | 0.05 ^d | 0.05 ^d |
| 1,1-Dichloroethene | NA | 0.25 ^c | 0.25 ^d | 0.25 ^d |
| Ethylbenzene | 0.02 - 2.34 | 1.13 | 1.75 | 1.75 |
| Methylene Chloride | 0.07 - 3.68 | 1.54 | 2.42 | 2.42 |
| Tetrachloroethene | 0.05 - 20.00 | 6.69 | 1.47 | 1.47 |
| Toluene | 0.07 - 18.64 | 7.20 | 6.83 | 6.83 |
| 1,1,1-Trichloroethane | 0.02 - 3.22 | 1.11 | 1.82 | 1.82 |
| Trichloroethene | 0.01 - 4.39 | 1.61 | 2.49 | 2.49 |
| Vinyl Chloride | <0.01 - 7.89 | 3.31 ^c | 1.67 ^d | 1.67 ^d |
| Xylene | NA | 4.04 ^c | 4.04 ^d | 4.04 ^d |

^aCranston factors based on emissions measured during October 1987 test program, except where noted.

^bFields Point factors based on Cranston emission factors, except where noted.

^cReported value is emission factor for one facility; no other data were available.

^dNot quantified in the Cranston test program. Emission factors based on literature sources.

TABLE 3-8. SUMMARY OF VOLATILE ORGANIC EMISSIONS FROM SEWAGE SLUDGE INCINERATORS
(mg emitted/dry kg of sludge burned)

| Compound | WERL A | WERL B | WERL | WERL | WERL | WERL | WERL | WERL | Average |
|--------------------------|--------------|--------------|------------------------|------------------------|------------------------|----------------------------------|-------------------------------|------|---------|
| | Reference 30 | Reference 30 | Site 1 Reference 25 | Site 2 Reference 26 | Site 3 Reference 27 | Site 4 Normal Reference 16 | Site 4 Hot Reference 16 | | |
| Acetonitrile | NR | NR | NR | NR | NR | 10.71 | 0.79 | | 5.75 |
| Acrylonitrile | NR | NR | 19.35 | 9.79 ^b | <0.03 | 35.58 | 0.52 | | 13.05 |
| Benzene | NR | 14.02 | 25.34 | 4.10 | 0.40 | 7.25 | 0.18 | | 8.55 |
| Bromodichloromethane | NR | 1.48 | NR | NR | NR | NR | NR | | 1.48* |
| Bromomethane | NR | 0.05 | NR | NR | NR | NR | NR | | 0.05* |
| 2-Butanone (MEK) | 6.98 | NR | NR | NR | NR | 9.11 | 0.05 | | 5.38 |
| Carbon Tetrachloride | <0.04 | NR | 0.16 | <0.01 | 0.01 | 0.02 | 0.01 | | 0.03 |
| Chlorobenzene | NR | 3.07 | 1.55 | 0.28 | <0.01 | 0.88 | 0.29 | | 1.01 |
| Chloroethane | NR | 0.80 | NR | NR | NR | NR | NR | | 0.80* |
| Chloromethane | NR | 5.16 | NR | NR | NR | NR | NR | | 5.16* |
| Chloroform | 8.50 | 4.15 | 7.60 | 0.47 | 3.88 | 0.41 | 0.52 | | 3.65 |
| 1,1-Dichloroethane | NR | 0.23 | NR | NR | NR | NR | NR | | 0.23* |
| 1,2-Dichloroethane | NR | NR | 0.04 | NR | <0.005 | NR | 0.03 | | 0.02 |
| trans-1,2-Dichloroethane | NR | 5.20 | 0.32 | 0.01 | <0.005 | 0.05 | NR | | 1.12 |
| 1,1,1-Dichloroethane | NR | 0.25 | NR | NR | NR | NR | NR | | 0.25* |
| Ethylbenzene | NR | 2.29 | 2.34 | 0.35 | 0.02 | 1.75 | 0.02 | | 1.13 |
| Methylene Chloride | NR | 2.16 | 3.68 | 0.45 | 0.07 | 2.42 | 0.44 | | 1.54 |
| Tetrachloroethene | 2.25 | 21.37 | 20.00 | 0.68 | 0.05 | 1.47 | 0.98 | | 6.69 |
| Toluene | 18.64 | NR | 7.69 | 9.24 | 0.07 | 6.83 | 0.70 | | 7.20 |
| 1,1,1-Trichloroethane | 0.71 | 3.22 | 0.50 | 0.02 | 0.04 | 1.82 | 1.47 | | 1.11 |
| Trichloroethene | 0.67 | 4.39 | 2.00 | 0.12 | 0.01 | 2.49 | 1.62 | | 1.61 |
| Vinyl Chloride | NR | 0.80 | 7.89 | 6.18 | <0.01 | 1.67 | NR | | 3.31 |
| Xylene | NR | 4.04 | NR | NR | NR | NR | NR | | 4.04* |

* Emission factor is based on data from only one site.

NR = Not reported.

TABLE 3-9. SEMIVOLATILE ORGANIC EMISSION ESTIMATES FOR CRANSTON AND
 FIELDS POINT SEWAGE SLUDGE INCINERATORS
 (mg emitted/kg dry sludge burned)

| Compound | Average from Literature Sources ^a | Cranston ^b | Fields Point ^b |
|----------------------------|---|-----------------------|------------------------------|
| <u>Acid Compounds</u> | | | |
| 2-Chlorophenol | <0.015 | 0.015 | 0.015 |
| 2,4-Dichlorophenol | <0.030 | 0.030 | 0.030 |
| 2,4-Dimethylphenol | <0.023 | 0.023 | 0.023 |
| 2,6-Dinitro-o-cresol | <0.119 | 0.119 | 0.119 |
| 2,4-Dinitrophenol | <0.515 | 0.515 | 0.515 |
| 2-Nitrophenol | 3.821 | 3.821 | 3.821 |
| 4-Nitrophenol | <0.285 | 0.285 | 0.285 |
| p-Chloro-m-cresol | <0.038 | 0.038 | 0.038 |
| Pentachlorophenol | <0.120 | 0.120 | 0.120 |
| Phenol | 34.542 | 34.542 | 34.542 |
| 2,4,6-Trichlorophenol | <0.046 | 0.046 | 0.046 |
| <u>Base Compounds</u> | | | |
| Benzo(a)pyrene | <0.022 | 0.022 | 0.022 |
| Bis(2-Ethylhexyl)phthalate | 1.019 | 1.019 | 1.019 |
| 1,2-Dichlorobenzene | 1.137 | 1.137 | 1.137 |
| 1,3-Dichlorobenzene | 0.864 | 0.864 | 0.864 |
| 1,4-Dichlorobenzene | 6.069 | 6.069 | 6.069 |
| Perchloroethylene | <0.040 | 0.040 | 0.040 |
| 1,2,4-Trichlorobenzene | <0.024 | 0.024 | 0.024 |

^aLess than values indicate the detection limit of nondetectable compounds.

^bNo semivolatile emission tests were performed on controlled stack gases at either Cranston or Fields Point. The values presented are order of magnitude type estimates based on literature sources. In most cases the emission factor estimate is based on detection limit of the analytical technique during the target analysis (i.e., most conservative estimate).

magnitude type emission estimates, compounds quantified and reported in the literature were used. In cases where compounds were not detected, the analytical detection limit was used as the emission estimates, which represents worst case scenario. Tables 3-10 and 3-11 contain summaries of semivolatile acid and base emission factors from literature sources.

3.4 PCB AND PESTICIDE EMISSIONS

PCBs and pesticides were not measured during the Cranston test program. Order of magnitude type emission estimates for both the Cranston and Fields Point incinerators are shown in Table 3-12. Although specifically targeted, PCBs and pesticides have not been quantified in emissions from sludge incinerators. Values in the table represent the analytical detection limits (expressed on emission factor basis). Table 3-13 contains detection limits reported during three test programs in which PCB and pesticide emissions were targeted.

3.5 DIOXIN AND FURAN EMISSIONS

Tables 3-14 and 3-15 present chlorinated dioxin and furan emission estimates for both Cranston and Fields Point. Emissions are expressed on an emission factor basis (ug/kg sludge) by congener and on a emission factor basis normalized to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents.

Presentation of CDDs and CDFs as 2,3,7,8-CDD toxic equivalents were developed by EPA for the purpose of deriving and reporting single emission values that relate directly to the toxicity of 2,3,7,8-TCDD.⁴⁰ Toxic equivalent factors were assigned to each CDD/CDF isomer or class and were multiplied by the emission factor for that isomer or class.

Tables 3-16 and 3-17 contain a summary of CDD and CDF emission factors based on literature sources of emission test at sludge incinerators. Note that the data base for these emissions consists of three series of tests conducted as part of the EPA National Dioxin study, and two test series conducted at the Cranston facility. One of the series of tests at Cranston

TABLE 3-10. SUMMARY OF ORGANIC ACID COMPOUND EMISSIONS
FROM SEWAGE SLUDGE INCINERATORS
(ug/kg dry sludge burned)

| Compound | WERL Site 1 ^a | WERL Site 2 ^b | WERL Site 3 ^c | Average |
|-----------------------|--------------------------|--------------------------|--------------------------|-----------------------|
| 2-Chlorophenol | <2,465 | <12.0 | <18.8 | <15.4 |
| 2,4-Dichlorophenol | <2,890 | <22.7 | <37.5 | <30.1 |
| 2,4-Dimethylphenol | <3,206 | <17.4 | <28.2 | <22.8 |
| 2,6-Dimethylphenol | <9,344 | <190.8 | <46.9 | <118.9 |
| 2,4-Dinitrophenol | <18,749 | <344.2 | <686.3 | <515.3 |
| 2-Nitrophenol | <5,616 | 3821.4 | <65.9 | 3,821.4 ^d |
| 4-Nitrophenol | <7,792 | <213.5 | <356.2 | <284.9 |
| p-Chloro-m-cresol | <3,989 | <28.0 | <46.9 | <37.5 |
| Pentachlorophenol | <5,568 | <89.4 | <150.3 | <119.9 |
| Phenol | <1,840 | 34,541.6 | <18.8 | 34,541.6 ^d |
| 2,4,6-Trichlorophenol | <3,886 | <34.7 | <56.5 | <45.6 |

^aReference 25, not included in average.

^bReference 26.

^cReference 27.

^dBased on emissions quantified at only one site.

TABLE 3-11. SUMMARY OF ORGANIC BASE COMPOUND EMISSIONS
FROM SEWAGE SLUDGE INCINERATORS
(ug emitted/kg dry sludge burned)

| Compound | WERL Site 1 ^a | WERL Site 2 ^b | WERL Site 3 ^c | Average |
|----------------------------|--------------------------|--------------------------|--------------------------|--------------------|
| Benzo(a)pyrene | <1,263 | <16.0 | <28.2 | <22.1 |
| Bis(2-Ethylhexyl)phthalate | 2,417 | 374.9 | 265.8 | 1,019.2 |
| 1,2-Dichlorobenzene | 2,677 | 732.5 | <18.8 | 1,136.5 |
| 1,3-Dichlorobenzene | 2,259 | 333.6 | <18.8 | 864.2 |
| 1,4-Dichlorobenzene | 6,069 | <13.3 | <18.8 | 6,069 ^d |
| Perchloroethylene | <2,993 | <33.4 | <46.9 | <40.2 |
| 1,2,4-Trichlorobenzene | <2,156 | <18.7 | <28.2 | <23.5 |

^aReference 25.

^bReference 26.

^cReference 27.

^dBased on emissions quantified at only one site.

TABLE 3-12. PESTICIDE, PCB, and DIOXIN/FURAN EMISSION ESTIMATES FOR CRANSTON AND FIELDS POINT SEWAGE SLUDGE INCINERATORS (ug emitted/kg dry sludge burned)

| Compound | Average from Literature Sources | Cranston ^a | Fields Point ^a |
|--|---------------------------------|-----------------------|---------------------------|
| Aldrin | <0.030 | 0.030 | 0.030 |
| Chlordane | <0.452 | 0.452 | 0.452 |
| Dieldrin | <0.046 | 0.046 | 0.046 |
| PCB-1242 | <0.452 | 0.452 | 0.452 |
| PCB-1254 | <0.542 | 0.542 | 0.542 |
| PCB-1221 | <0.452 | 0.452 | 0.452 |
| PCB-1232 | <0.452 | 0.452 | 0.452 |
| PCB-1248 | <0.542 | 0.542 | 0.542 |
| PCB-1260 | <0.542 | 0.542 | 0.542 |
| PCB-1016 | <0.452 | 0.452 | 0.452 |
| 2,3,7,8-TCDD (toxic equivalents) ^c | | 0.097 ^b | 0.097 ^b |

^aNo pesticide or PCB emission tests were performed at Cranston or Fields Point. The values presented are order of magnitude type estimates based on emissions measured at other incinerators (see Table 3-13). In all cases, the emission factor estimate is based on the detection limit of nondetectable compounds. This approach results in a worst case type emission estimate.

^bDioxin and furan emissions were measured at the Cranston facility. The 2,3,7,8-TCDD toxic equivalent factor derived for Cranston is also used for Fields Point.

^cReference 40.

TABLE 3-13. SUMMARY OF PCB AND PESTICIDE EMISSIONS
FROM SEWAGE SLUDGE INCINERATORS
(ug emitted/kg dry sludge burned)

| Compound | WERL Site 1 ^a | WERL Site 2 ^b | WERL Site 3 ^c | Average |
|-----------|--------------------------|--------------------------|--------------------------|---------|
| Aldrin | <12,495 | <22.7 | <37.5 | <30.1 |
| Chlordane | NR | <340.2 | <562.9 | <451.6 |
| Dieldrin | <11,286 | <34.7 | <56.3 | <45.5 |
| PCB-1242 | NR | <340.2 | <562.9 | <451.6 |
| PCB-1254 | NR | <408.3 | <675.9 | <542.1 |
| PCB-1221 | NR | <340.2 | <562.9 | <451.6 |
| PCB-1232 | NR | <340.2 | <562.9 | <451.6 |
| PCB-1248 | NR | <408.3 | <675.9 | <542.1 |
| PCB-1260 | NR | <408.3 | <675.9 | <542.1 |
| PCB-1016 | NR | <340.2 | <562.9 | <451.6 |

^aReference 25, not included in average.

^bReference 26.

^cReference 27.

TABLE 3-14. CHLORINATED DIOXIN EMISSION FACTORS USED AS INPUTS TO DISPERSION MODELING

| Congener | Cranston ^a ug/kg | Fields Point ^b ug/kg | 2,3,7,8-ICDD Cranston ug/kg | Toxic Equivalents ^c Fields Point ug/kg |
|---------------------|--------------------------------|------------------------------------|-----------------------------------|---|
| Total MCDD | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Total DCDD | 0.0974 | 0.0974 | 0.0000 | 0.0000 |
| Total TriCDD | 0.2021 | 0.2021 | 0.0000 | 0.0000 |
| 2,3,7,8-TCDD | 0.0024 | 0.0024 | 0.0024 | 0.0024 |
| Other TCDD | 0.1343 | 0.1343 | 0.0013 | 0.0013 |
| 1,2,3,7,8-PCDD | 0.0027 | 0.0027 | 0.0014 | 0.0014 |
| Other PCDD | 0.0479 | 0.0479 | 0.0002 | 0.0002 |
| 1,2,3,4,7,8-HxCDD | 0.0012 | 0.0012 | 0.0001 | 0.0001 |
| 1,2,3,6,7,8-HxCDD | 0.0024 | 0.0024 | 0.0001 | 0.0001 |
| 1,2,3,7,8,9-HxCDD | 0.0045 | 0.0045 | 0.0002 | 0.0002 |
| Other HxCDD | 0.0315 | 0.0315 | 0.0000 | 0.0000 |
| 1,2,3,4,6,7,8-HpCDD | 0.0094 | 0.0094 | 0.0000 | 0.0000 |
| Other HpCDD | 0.0100 | 0.0100 | 0.0000 | 0.0000 |
| OCDD | 0.0243 | 0.0243 | 0.0000 | 0.0000 |
| TOTALS | 0.5701 | 0.5701 | 0.0057 | 0.0057 |

^aEmission factor derived from measurements at Cranston.

^bOrder of magnitude type estimates based on Cranston measurements.

^cReference 40.

TABLE 3-15. CHLORINATED FURAN EMISSION FACTORS USED AS INPUTS TO DISPERSION MODELING

| Congener | Cranston ^a ug/kg | Fields Point ^b ug/kg | 2,3,7,8-TCDD Cranston ug/kg | Toxic Equivalents ^c Fields Point ug/kg |
|---------------------|--------------------------------|------------------------------------|-----------------------------------|---|
| Total MCDF | 0.0385 | 0.0385 | 0.0000 | 0.0000 |
| Total DCDF | 0.2665 | 0.2665 | 0.0000 | 0.0000 |
| Total TriCDF | 0.8399 | 0.8399 | 0.0000 | 0.0000 |
| 2,3,7,8-TCDF | 0.0804 | 0.0804 | 0.0804 | 0.0804 |
| Other TCDF | 0.5196 | 0.5196 | 0.0052 | 0.0052 |
| 1,2,3,7,8-PCDF | 0.0079 | 0.0079 | 0.0040 | 0.0040 |
| 2,3,4,7,8-PCDF | 0.0206 | 0.0206 | 0.0001 | 0.0001 |
| Other PCDF | 0.1515 | 0.1515 | 0.0008 | 0.0008 |
| 1,2,3,4,7,8-HxCDF | 0.0153 | 0.0153 | 0.0002 | 0.0002 |
| 1,2,3,6,7,8-HxCDF | 0.0058 | 0.0058 | 0.0001 | 0.0001 |
| 2,3,4,6,7,8-HxCDF | 0.0081 | 0.0081 | 0.0001 | 0.0001 |
| 1,2,3,7,8,9-HxCDF | 0.0007 | 0.0007 | 0.0000 | 0.0000 |
| Other HxCDF | 0.0442 | 0.0442 | 0.0000 | 0.0000 |
| 1,2,3,4,6,7,8-HpCDF | 0.0157 | 0.0157 | 0.0000 | 0.0000 |

TABLE 3-15. (Continued)

| Congener | Cranston ^a ug/kg | Fields Point ^b ug/kg | 2,3,7,8-TCDD Cranston ug/kg | Toxic Equivalents ^c Fields Point ug/kg |
|---------------------|--------------------------------|------------------------------------|-----------------------------------|---|
| 1,2,3,4,7,8,9-HpCDF | 0.0018 | 0.0018 | 0.0000 | 0.0000 |
| Other HpCDF | 0.0536 | 0.0536 | 0.0000 | 0.0000 |
| OCDF | 0.0062 | 0.0062 | 0.0000 | 0.0000 |
| TOTALS | 2.0763 | 2.0763 | 0.0909 | 0.0909 |

^aEmission factor derived from measurements at Cranston.

^bOrder of magnitude type estimate based on Cranston measurements.

^cReference 40.

TABLE 3-16. SUMMARY OF CHLORINATED DIOXIN EMISSIONS FROM SEWAGE SLUDGE INCINERATORS
(ug dioxin emitted/kg dry sludge burned)

| Site Furnace Type ^a Control Technology ^b Reference | SSI-A MHF V & I 34 | | SSI-B MHF V 34 | | SSI-C MHF I 34 | | Cranston Normal MHF V & I 16 | | Cranston Hot MFH V & I + AB 16 | | Average |
|---|-----------------------------|-----------------------|-------------------------|-----------------------|-------------------------|---------|--|--------|--|----------|----------|
| | | | | | | | | | | | |
| Total MCDD | NR ^c | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Total DCDD | NR | NR | NR | NR | NR | NR | 0.0974 | 0.0416 | 0.0416 | 0.0695 | 0.0695 |
| Total TriCDD | NR | NR | NR | NR | NR | NR | 0.2021 | 0.1116 | 0.1116 | 0.1567 | 0.1567 |
| 2,3,7,8-TCDD | 0.00022 | <0.0003 ^d | <0.0003 ^d | <0.0003 ^d | 0.00094 | 0.00094 | 0.0024 | 0.0009 | 0.0009 | 0.0009 | 0.0009 |
| Total TCDD | 0.05702 | 0.0013 | 0.0013 | 0.0013 | 0.05464 | 0.05464 | 0.1367 | 0.1392 | 0.1392 | 0.0777 | 0.0777 |
| 1,2,3,7,8-PCDD | NR | NR | NR | NR | NR | NR | 0.0027 | 0.0025 | 0.0025 | 0.0026 | 0.0026 |
| Total PCDD | 0.00076 | <0.00055 ^d | <0.00055 ^d | <0.00055 ^d | 0.00723 | 0.00723 | 0.0506 | 0.0757 | 0.0757 | 0.0268 | 0.0268 |
| 1,2,3,4,7,8-HxCDD | NR | NR | NR | NR | NR | NR | 0.0012 | 0.0017 | 0.0017 | 0.00145 | 0.00145 |
| 1,2,3,6,7,8-HxCDD | NR | NR | NR | NR | NR | NR | 0.0024 | 0.0037 | 0.0037 | 0.000305 | 0.000305 |
| 1,2,3,7,8,9-HxCDD | NR | NR | NR | NR | NR | NR | 0.0045 | 0.0053 | 0.0053 | 0.0049 | 0.0049 |
| Total HxCDD | 0.00262 | <0.00136 ^d | <0.00136 ^d | <0.00136 ^d | 0.04710 | 0.04710 | 0.0396 | 0.0600 | 0.0600 | 0.02139 | 0.02139 |
| 1,2,3,4,6,7,8-HpCDD | NR | NR | NR | NR | NR | NR | 0.0094 | 0.0106 | 0.0106 | 0.0100 | 0.0100 |
| Total HpCDD | 0.01320 | 0.00059 | 0.00059 | 0.00059 | 0.1480 | 0.1480 | 0.0194 | 0.0233 | 0.0233 | 0.04090 | 0.04090 |
| OCDD | 0.02940 | 0.00309 | 0.00309 | 0.00309 | 0.1060 | 0.1060 | 0.0243 | 0.0121 | 0.0121 | 0.03500 | 0.03500 |
| Total Tetra-Octa CDD | 0.10300 | 0.00481 ^d | 0.00481 ^d | 0.00481 ^d | 0.36297 | 0.36297 | 0.2706 | 0.3103 | 0.3103 | 0.21034 | 0.21034 |
| Total Mono-Octa CDD | --- | --- | --- | --- | --- | --- | 0.5701 | 0.4635 | 0.4635 | 0.5168 | 0.5168 |

^aMHF = Multiple hearth furnace.

^bV = Venturi scrubber; I = Impingement tray scrubber; AB = Afterburner.

^cNR = Not reported.

^dFor averaging purposes, values below detection limit are assigned a value of zero.

TABLE 3-17. SUMMARY OF CHLORINATED FURAN EMISSIONS FROM SEWAGE SLUDGE INCINERATORS
(ug dioxin emitted/kg dry sludge burned)

| Site Furnace Type ^a Control Technology ^b Reference | SSI-A MHF V & I 34 | SSI-B MHF V 34 | SSI-C MHF I 34 | Cranstog Normal MHF V & I 16 | Cranstog Hot MHF V & I + AB 16 | Average |
|---|-----------------------------|-------------------------|-------------------------|--|--|---------|
| Total MCDF | NR | NR | NR | 0.0385 | 0.0422 | 0.0404 |
| Total DCDF | NR | NR | NR | 0.2665 | 0.2809 | 0.2737 |
| Total TriCDF | NR | NR | NR | 0.8399 | 0.6160 | 0.7280 |
| 2,3,7,8-TCDF | NR | 0.00671 | 0.3520 | 0.0804 | 0.0537 | 0.1232 |
| Total TCDF | 0.1730 | 0.06431 | 1.3460 | 0.6000 | 0.3500 | 0.4721 |
| 1,2,3,7,8-PCDF | NR | NR | NR | 0.0079 | 0.0042 | 0.0061 |
| 2,3,4,7,8-PCDF | NR | NR | NR | 0.0206 | 0.0138 | 0.0172 |
| Total PCDF | 0.0530 | 0.0143 | 0.6920 | 0.1800 | 0.1300 | 0.2139 |
| 1,2,3,4,7,8-HxCDF | NR | NR | NR | 0.0153 | 0.01760 | 0.0165 |
| 1,2,3,6,7,8-HxCDF | NR | NR | NR | 0.0058 | 0.0060 | 0.0059 |
| 2,3,4,5,7,8-HxCDF | NR | NR | NR | 0.0081 | 0.01100 | 0.0096 |
| 1,2,3,7,8,9-HxCDF | NR | NR | NR | 0.0007 | 0.0006 | 0.0007 |
| Total HxCDF | 0.00080 | 0.0043 | 0.2210 | 0.07410 | 0.0777 | 0.0756 |
| 1,2,3,4,6,7,8-HpCDF | NR | NR | NR | 0.0157 | 0.0302 | 0.0230 |
| 1,2,3,4,7,8,9-HpCDF | NR | NR | NR | 0.0018 | 0.0028 | 0.0023 |
| Total HpCDF | 0.00264 | <0.0016 | 0.4300 | 0.07110 | 0.0479 | 0.1103 |
| OCDF | 0.00041 | 0.00020 | 0.3250 | 0.0062 | 0.0077 | 0.0079 |
| <hr/> | | | | | | |
| Total Tetra-Octa CDF | 0.2299 | 0.08311 | 3.014 | 0.9314 | 0.6133 | 0.9743 |
| Total Mono-Octa CDF | --- | --- | --- | 2.0763 | 1.5524 | 1.8144 |

^aMHF = Multiple hearth furnace.

^bV = Venturi scrubber; I = Impingement tray scrubber; AB = Afterburner.

^cNR = Not reported.

^dFurnace operating conditions are characterized in detail and presented in Table 5-2 of this document.

was performed while the furnace and air pollution control systems were being operated under normal conditions. The second test series at Cranston was performed during periods in which the auxiliary afterburner was used and the furnace was intentionally maintained at temperatures much hotter than normal.

4.0 RISK ASSESSMENT

In general, risk assessments can be performed at various levels of detail ranging from a screening analysis to a very refined analysis. The latter uses sophisticated pollutant fate and transport models to estimate environmental concentrations in air, water, and soil and subsequent human exposure via multiple pathways (i.e., inhalation, ingestion, and dermal routes). The objective of this risk assessment was to provide a screening level analysis of exposure and risk related to human exposure to emitted pollutants via the inhalation pathway. Results of this analysis include an estimate of exposure and resulting health effects for both carcinogenic and noncarcinogenic pollutants determined to be emitted from the two incinerators. Table 4-1 lists the specific carcinogens and noncarcinogens included.

The following two sections describe the methods used in developing the screening analysis and the results of those analyses.

4.1 EXPOSURE AND RISK ESTIMATION METHODOLOGY

This section summarizes the methods used to estimate human exposure and risk from incinerator emissions of hazardous pollutants. This analysis includes estimation of exposure and risk from inhalation of the pollutants and does not include an analysis of either pollutant ingestion (resulting from the consumption of local crops, soil, or water contaminated via atmospheric deposition) or dermal contact. In this study it was assumed that the inhalation pathway represents the majority of human exposure resulting from incinerator-based emissions. Therefore, modeling in this study was confined to inhalation.

In general, three steps are followed in estimating incinerator-based human exposure and risk: 1) estimation of ambient air pollutant concentrations using atmospheric dispersion models, 2) exposure assessment (i.e., matching of ambient air concentrations with exposed population), and

TABLE 4-1. CARCINOGENIC AND NONCARCINOGENIC POLLUTANTS

| Noncarcinogenic Pollutants | CAS No. | Carcinogenic Pollutants | CAS No. |
|---------------------------------|------------|----------------------------|------------|
| ACETONITRILE | 75-05-8 | ACRYLONITRILE | 107-13-1 |
| ALDRIN | 309-00-2 | ARSENIC | 7440-38-2 |
| BROMODICHLOROMETHANE | 75-27-4 | BENZENE | 71-43-2 |
| BROMOMETHANE (METHYL BROMIDE) | 74-83-9 | BENZO(A)PYRENE | 50-32-8 |
| 2-BUTANONE (MEK) | 78-93-3 | BERYLLIUM | 7440-41-7 |
| CHLOROBENZENE | 108-90-7 | BIS(2-ETHYLHEXYL)PHTHALATE | 117-81-7 |
| P-CHLORO-M-CRESOL | 59-50-7 | CADMIUM | 7440-43-9 |
| CHLORODANE | 57-74-9 | CARBON TETRACHLORIDE | 56-23-5 |
| CHLOROETHANE (ETHYL CHLORIDE) | 75-00-3 | CHLOROFORM | 67-66-3 |
| CHLOROMETHANE (METHYL CHLORIDE) | 74-87-3 | CHROMIUM VI | 7440-47-3 |
| 2-CHLOROPHENOL | 95-57-8 | 1,2,-DICHLOROETHANE | 107-06-2 |
| CHROMIUM | 7440-47-3 | METHYLENE CHLORIDE | 75-09-2 |
| COPPER | 7440-50-8 | NICKEL | 7440-02-0 |
| 1,2-DICHLOROBENZENE | 95-50-1 | PCB-1016 | |
| 1,3-DICHLOROBENZENE | 541-73-1 | PCB-1221 | |
| 1,4-DICHLOROBENZENE | 106-46-7 | PCB-1232 | |
| 1,1-DICHLOROETHANE | 75-34-3 | PCB-1242 | 53469-21-9 |
| 1,1-DICHLOROETHENE | 75-35-4 | PCB-1248 | |
| 2,4-DICHLOROPHENOL | 25167-81-1 | PCB-1254 | 11097-69-1 |
| DIELDRIN | 60-57-1 | PCB-1260 | |
| 2,4-DIMETHYLPHENOL | 1300-71-6 | TOTAL PCBs | 1336-36-3 |
| 2,6-DINITRO-O-CRESOL | 534-52-1 | PERCHLOROETHYLENE | 127-18-4 |
| 2,4-DINITROPHENOL | 51-28-5 | 2378 TCDD | 1746-01-6 |
| ETHYLBENZENE | 100-41-4 | TETRACHLOROETHENE | 127-18-4 |
| LEAD | 7439-92-1 | TRICHLOROETHENE | 79-01-6 |
| 2-NITROPHENOL | 88-75-5 | VINYL CHLORIDE | 75-01-4 |
| 4-NITROPHENOL | 100-02-7 | | |
| PENTACHLOROPHENOL | 87-86-5 | | |
| PHENOL | 108-75-2 | | |
| SELENIUM | 7752-49-2 | | |
| TOLUENE | 108-88-3 | | |
| 1,2,4-TRICHLOROBENZENE | 120-82-1 | | |
| 1,1,1-TRICHLOROETHANE | 71-55-6 | | |
| 2,4,6-TRICHLOROPHENOL | 88-06-2 | | |
| XYLENE | 1330-20-7 | | |
| ZINC | 7440-66-6 | | |

3) characterization of potential health risk to the exposed population. A summary of the procedures followed to conduct the exposure and risk assessment follows; a more complete description of the procedures, and specifically the computer models used, appears in Appendix C.

4.1.1 Estimation of Ambient Air Pollutant Concentrations

The Industrial Source Complex (ISC) atmospheric dispersion model was used to estimate the ambient air concentrations resulting from pollutant emissions from the incinerators.³⁵ ISC is an EPA-approved guideline model. The ISC model has both a short-term (ISCST) version and a long-term (ISCLT) version. ISCST is used to estimate ground level concentrations on an hourly basis for periods up to a year. ISCLT is used to estimate annual average ground level concentrations. In this study ISCLT was used to estimate both carcinogenic and noncarcinogenic pollutant concentrations. These long-term average concentrations were used to estimate the risk of cancer and indicate the likelihood of adverse health effects due to chronic exposure to noncarcinogens. ISCST was used in a screening mode to predict a maximum 24-hour concentration likely to occur. This concentration was used to characterize the likelihood of acute health effects due to short-term exposures.

To execute the ISC models, three sets of input data are necessary: 1) emission source characterizations, 2) meteorological data representative of the study area, and 3) model-specific option settings. Table 4-2 lists the specific emission source characteristics, excluding emission rate, used to perform the atmospheric dispersion modeling for the Cranston and Fields Point facilities. These data were either gathered during site visits, supplied by Rhode Island DEM personnel, or generated by reviewing facility plot plans. Emission rate estimates used to perform the modeling were presented and discussed in Section 3.0 of this document.

The meteorological data used for ISCLT were supplied by the Rhode Island DEM and represent data from the Providence/Francis/Green National Weather Service (NWS) site for the years 1968 to 1972. Because ISCST was executed in a screening mode, NWS hourly sequential meteorological data

TABLE 4-2. SOURCE CHARACTERISTICS FOR INCINERATION FACILITIES

| Source Characteristics | Incineration Facility | |
|---------------------------|-----------------------|-------------|
| | Fields Point | Cranston |
| Latitude | 41° 47' 27" | 41° 45' 00" |
| Longitude | 71° 23' 15" | 71° 26' 00" |
| Stack Height (meters) | 21.6 | 23.2 |
| Exit Gas Velocity (m/sec) | 1.15 | 12.2 |
| Exit Gas Temperature (°K) | 316 | 323 |
| Stack Diameter (meters) | 1.1 | 0.46 |
| Building Height (meters) | 15.5 | 15.2 |
| Building Width (meters) | 13.8 | 25.9 |

were not used. Rather, worst case hourly meteorological data were used to estimate a single maximum short term 1-hour average concentration. The maximum 1-hour average concentration was converted to a maximum 24-hour average concentration using the factor 0.4, recommended in the EPA report Guidelines on Air Quality Maintenance Planning and Analysis, Volume 10R.³⁶

The model-specific options required for execution of ISC for this study are listed in Table 4-2.

4.1.2 Exposure Assessment Methodology

The objective of most exposure assessments is to match the predicted ambient concentrations to the population residing in the study area and estimate the levels to which people are exposed. The EPA Human Exposure Model (HEM) was used to estimate human exposure to the carcinogenic pollutants included in this study.³⁷ The HEM is a computer model that matches ambient concentrations with the population to estimate human exposure. The model combines a data base reflecting U.S. Census Bureau residence-based population data from the 1980 census with the ambient concentrations predicted by ISCLT. The HEM reports both the exposure level associated with the maximum exposed individual and the aggregate exposure reflecting the total population exposure.

For noncarcinogenic pollutants no attempt was made to match concentrations with specific populations. Instead the maximum concentrations predicted by ISC were reported here as the maximum level to which anyone in the study area was potentially exposed. These data were reported on both a short-term (24-hour) and long-term basis (annual).

4.1.3 Risk Characterization Methodology

In characterizing the risk of potential health effects the HEM calculated exposure and risk measures and the Rhode Island AAL levels were used for carcinogenic pollutants, and a comparison with the Rhode Island Acceptable Ambient Level (AAL) were used for noncarcinogenic pollutants. The AAL is the maximum allowable ambient air concentrations of a toxic air contaminant listed in the Rhode Island Air Toxics Regulations

at or beyond the facility's property fenceline. In general, Rhode Island AALs for carcinogens are established based on individual lifetime cancer risks in the range of 10^{-6} to 10^{-5} .³⁹ For carcinogenic pollutants in this study the following two risk measures were estimated for both the Cranston and the Fields Point incinerators:

1. Maximum Exposed Individual (MEI)

The MEI is a measure of the maximum long-term average ambient air concentration that anyone in the study area (i.e., within 50 km of an incinerator) will experience. This value can be compared directly to the Rhode Island annual average AAL value.

2. Maximum Individual Risk (MIR)

The MIR is a measure of the estimated risk of cancer to the maximum exposed individuals. It is computed by multiplying the exposure for the MEI by the pollutant cancer unit risk factor (URF). The URF represents the probability of contracting cancer given a lifetime exposure to 1 microgram per cubic meter of the pollutant in the breathing air. When multiplied by an actual or estimated exposure the result is an estimate of the risk of cancer due to a lifetime exposure. Rhode Island AAL values are generally based on individual lifetime risks in the 10^{-6} to 10^{-5} range.

For noncarcinogens the following measures of exposure were estimated for the two incinerators:

1. Maximum Exposed Individual - Annual Average

The maximum exposed individual is a measure of the maximum annual average ambient concentration that anyone in the study area (i.e., within 50 km of an incinerator) is predicted to experience. This exposure value can be compared to the Rhode Island annual average AAL value.

2. Maximum Exposed Individual - 24-hour Average

The maximum exposed individual is a measure of the maximum 24-hour average ambient concentration that anyone in the study area (i.e., within 50 km of an incinerator) will experience. This exposure value can be compared to the Rhode Island 24-hour average AAL value.

Rhode Island has developed a set of procedures discussed in Rhode Island Air Standard Setting Procedures that is used to determine the need to list a substance as toxic and discusses the development of an acceptable ambient level (AAL) of exposure to the substance.³⁹ Criteria used in evaluating the substance include:

- absorption, metabolism, and excretion;
- physical and chemical information;
- mutagenicity;
- carcinogenicity;
- teratogenicity/fetotoxicity/reproductive effects;
- other toxic effects; and
- existing standards and guidelines.

An acceptable risk for substances with sufficient or substantial effects of carcinogenicity, or that have been classified by IARC or NTP as "sufficient animal," is in the range of 10^{-5} to 10^{-6} for an individual lifetime risk. Other criteria have been adopted that adjust LOAEL's (Lowest Adverse Effect Level) and NOAEL's (No Adverse Effect Level) derived from human occupational studies of acceptable quality and derived from animal studies on human experimental exposures using factors discussed in the Air Standard Setting Procedures.

Together these measures of exposure and risk form the basis of risk management decisions concerning the operation of the incineration facilities.

4.2 EXPOSURE AND RISK RESULTS

This section discusses the results of the exposure/risk assessment analysis. Figure 4-1 shows annual average concentration isopleths for the ISCLT results based on a 1 gram per second emission rate. To the north, east, and west of the Cranston incinerator the distance where the concentration falls below 0.05 ug/m^3 extends to 7 kilometers. The concentration

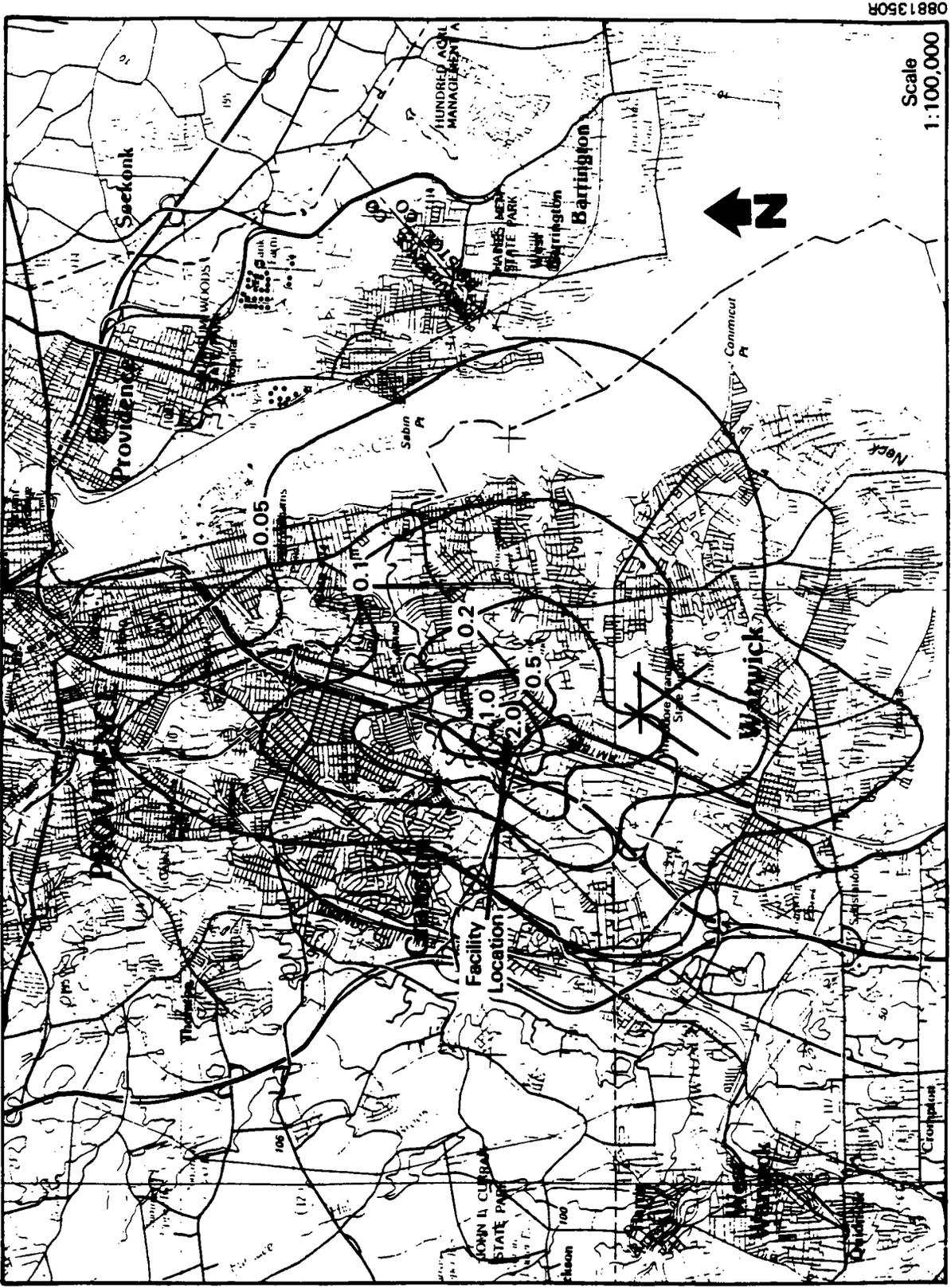


Figure 4-1. Cranston - Annual Average Concentration ($\mu\text{g}/\text{m}^3$)
Based on a 1 gram/second Emission Rate

value of 0.05 ug/m^3 was arbitrarily selected since the concentration value at any given location must be multiplied by the pollutant-specific emission rate to calculate the actual concentration.

Figure 4-2 shows the annual average concentration isopleths for the Fields Point incinerator. The annual average concentrations shown in this figure were also based on ISCLT model results using a 1 gram per second emission rate. As expected, the general shape of the isopleths is similar to those shown in Figure 4-1 for the Cranston incinerator.

Figure 4-3 shows the population density (people/km^2) in an approximately 20-kilometer-square area centered around the Cranston and Field Point incinerators. The population density is overlaid on grid cells that are 3-square-kilometers in size. The area of greatest population density is to the east of the Fields Point incinerator and north of the Cranston incinerator. The combination of the annual average concentration isopleths shown in Figures 4-1 and 4-2, and the population density shown in Figure 4-3 shows the location of population exposed to pollutant concentrations from the incinerator emissions.

4.2.1 Carcinogen Exposure and Risk

Tables 4-3 and 4-4 contain pollutant-specific data for the following measures:

- emission rate (rate at which pollutant is emitted into the atmosphere after incineration),
- unit cancer risk factor (from EPA and CAG),
- maximum individual exposure (maximum annual average concentration predicted using ISCLT scaled by pollutant-specific emission rate),
- The Rhode Island annual average AAL and the AAL with LAER in mg/m^3 ,
- maximum individual risk, and
- estimated increase in total annual cancer incidence due to incinerator emissions.

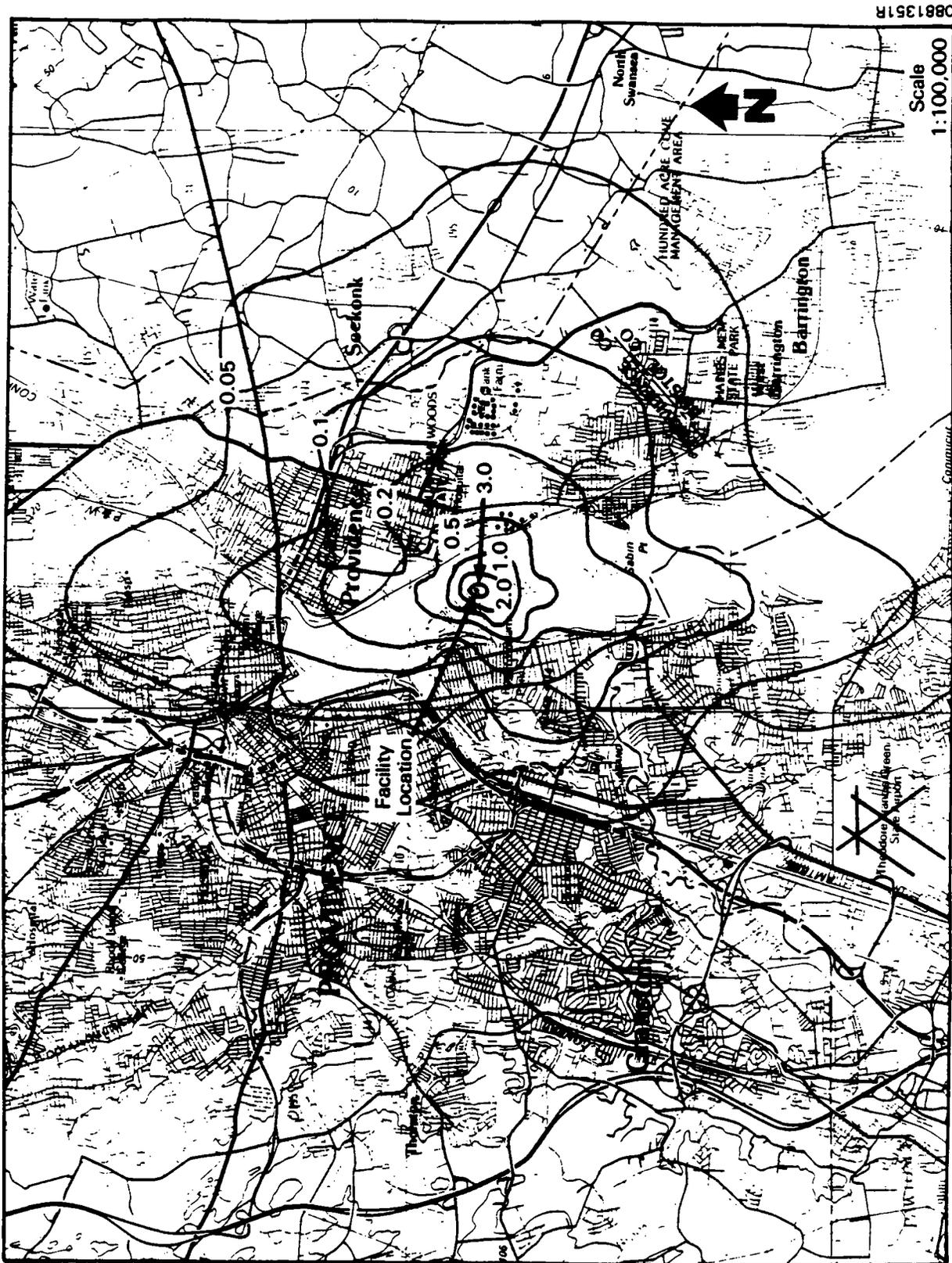


Figure 4-2. Providence (Fields Point) - Annual Average Concentration ($\mu\text{g}/\text{m}^3$)
Based on a 1 gram/second Emission Rate

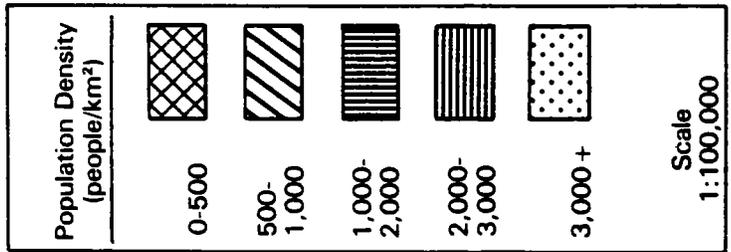
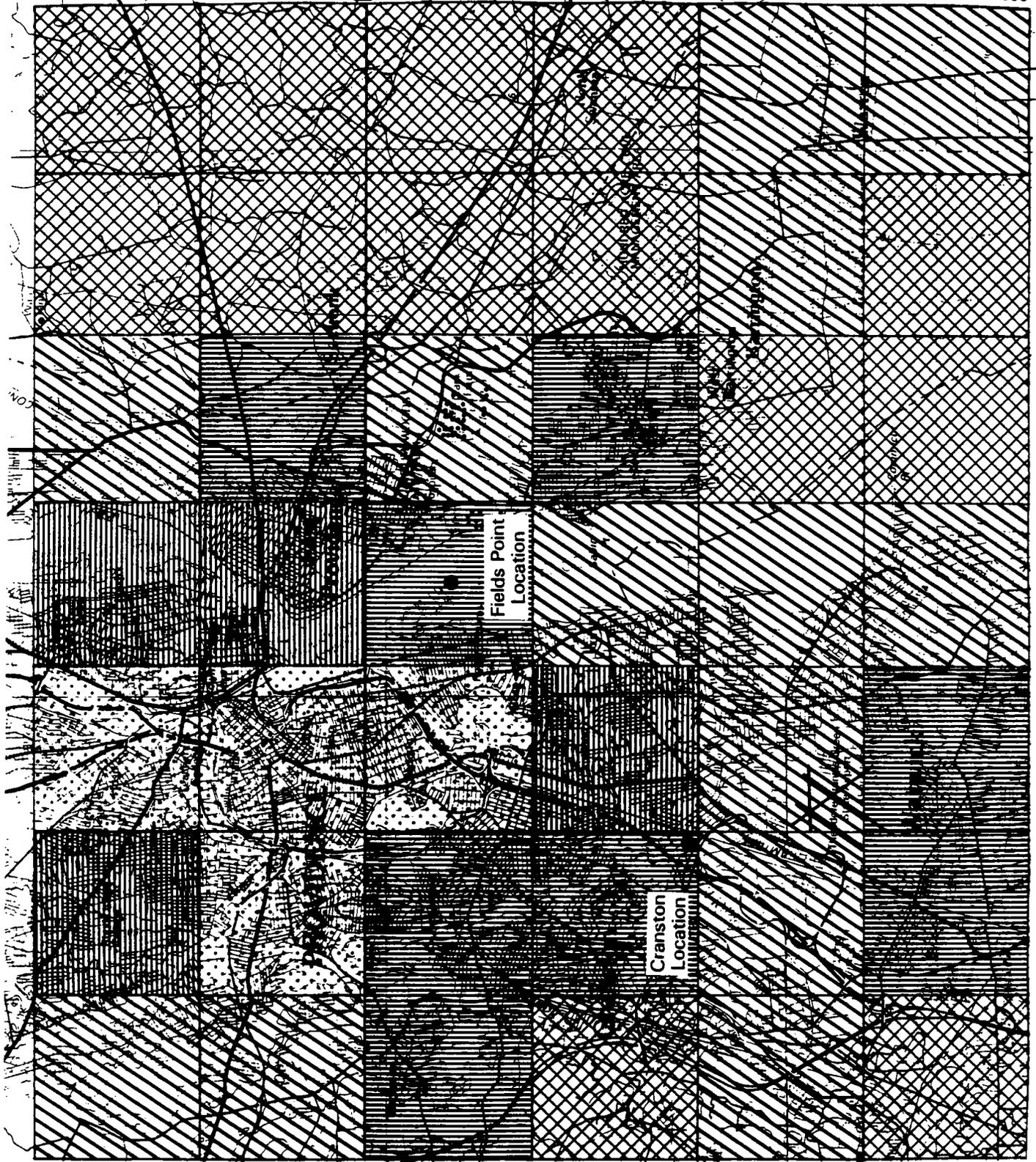


Figure 4-3. Providence, Rhode Island - Population Density (people/km²)

TABLE 4-3. SUMMARY OF HEM MODEL RESULTS - CRANSTON FACILITY

| CARCINOGEN POLLUTANTS | CAS NO. | EMISSION RATE ^a (G/HR) | UNIT RISK FACTOR ^b | RHODE ISLAND | | RHODE ISLAND | | MAXIMUM INDIVIDUAL RISKE |
|----------------------------|------------|---|----------------------------------|--------------------------|---------------------------------|--------------------------|---------------------------------|--------------------------------|
| | | | | CONCENTRATION (UG/M3) | AVERAGE ^c (UG/M3) | CONCENTRATION (UG/M3) | AVERAGE ^d (UG/M3) | |
| VOCs: | | | | | | | | |
| ACRYLONITRILE | 107-13-1 | 2.06E+01 | 6.80E-05 | 2.01E-02 | 7.00E-02 | 7.00E-01 | 7.00E-01 | 1.37E-06 |
| BENZENE | 71-43-2 | 4.17E+00 | 8.30E-06 | 4.08E-03 | 1.00E-01 | 1.00E+00 | 1.00E+00 | 3.38E-08 |
| CARBON TETRACHLORIDE | 56-23-5 | 1.15E-02 | 1.50E-05 | 1.12E-05 | 3.00E-02 | 3.00E-01 | 3.00E-01 | 1.69E-10 |
| CHLOROFORM | 67-66-3 | 2.36E-01 | 2.30E-05 | 2.31E-04 | 4.00E-02 | 4.00E-01 | 4.00E-01 | 5.30E-09 |
| 1,2-DICHLOROETHANE | 107-06-2 | 1.15E-02 | 2.60E-05 | 1.12E-05 | 4.00E-02 | 4.00E-01 | 4.00E-01 | 2.92E-10 |
| METHYLENE CHLORIDE | 75-09-2 | 1.39E+00 | 4.70E-07 | 1.36E-03 | 2.00E-01 | 2.00E+00 | 2.00E+00 | 6.39E-10 |
| TETRACHLOROETHENE | 127-18-4 | 8.45E-01 | 5.80E-07 | 8.26E-04 | 5.00E-02 | 5.00E-01 | 5.00E-01 | 4.79E-10 |
| TRICHLOROETHENE | 79-01-6 | 1.43E+00 | 1.30E-06 | 1.40E-03 | 3.00E+00 | 3.00E-01 | 3.00E-01 | 1.82E-09 |
| VINYL CHLORIDE | 75-01-4 | 9.60E-01 | 4.10E-06 | 9.39E-04 | | | | 3.85E-09 |
| BASE COMPOUNDS: | | | | | | | | |
| BENZO(A)PYRENE | 50-32-8 | < 1.27E-02 ^f | 2.30E-03 | 1.24E-05 ^j | | | 5.00E+00 ^k | 2.84E-08 ^j |
| BIS(2-ETHYLHEXYL)PHTHALATE | 117-81-7 | 5.86E-01 ^g | 1.30E-07 | 5.73E-04 | 5.00E-01 ^k | | | 7.45E-11 |
| PCBS AND DIOXIN: | | | | | | | | |
| PCB-1242 | 53469-21-9 | < 2.60E-04 ^f | 1.20E-03 | 2.54E-07 ^j | | | | 3.05E-10 ^j |
| PCB-1254 | 11097-69-1 | < 3.12E-04 ^f | 1.20E-03 | 3.05E-07 ^j | | | | 3.66E-10 ^j |
| PCB-1221 | | < 2.60E-04 ^f | 1.20E-03 | 2.54E-07 ^j | | | | 3.05E-10 ^j |
| PCB-1232 | | < 2.60E-04 ^f | 1.20E-03 | 2.54E-07 ^j | | | | 3.05E-10 ^j |
| PCB-1248 | | < 3.12E-04 ^f | 1.20E-03 | 3.05E-07 ^j | | | | 3.66E-10 ^j |
| PCB-1260 | | < 3.12E-04 ^f | 1.20E-03 | 3.05E-07 ^j | | | | 3.66E-10 ^j |
| PCB-1016 | | < 2.60E-04 ^f | 1.20E-03 | 2.54E-07 ^j | | | | 3.05E-10 ^j |
| TOTAL PCBs | 1336-36-3 | < 1.97E-03 ^f | 1.20E-03 | 1.93E-06 ^j | | | | 2.32E-09 ^j |
| 2378 TCDD | 1746-01-6 | 5.55E-05 | 3.30E+01 | 5.43E-08 | | | | 1.79E-06 |

(Continued)

TABLE 4-3. SUMMARY OF HEM MODEL RESULTS - CRANSTON FACILITY

| CARCINOGEN POLLUTANTS | CAS NO. | EMISSION RATE ^a (G/HR) | UNIT RISK FACTOR ^b | RHODE ISLAND RHODE ISLAND | | MAXIMUM INDIVIDUAL RISK ^e |
|-----------------------|-----------|-----------------------------------|-------------------------------|---|--|--------------------------------------|
| | | | | MAXIMUM AVERAGE ANNUAL CONCENTRATION (UG/M3) ^c | AAL W/LAER ANNUAL AVERAGE ^d (UG/M3) | |
| ARSENIC (as As) | 7440-38-2 | 2.30E-02 | 4.30E-03 | 2.25E-05 | 2.00E-04 | 9.67E-08 |
| BERYLLIUM | 7440-41-7 | < 1.15E-03 ^h | 2.40E-03 | 1.12E-06 ^j | | 2.70E-09 ^j |
| CADMIUM | 7440-43-9 | 1.56E+00 | 1.80E-03 | 1.53E-03 | 6.00E-04 | 2.75E-06 |
| CHROMIUM VI | 7440-47-3 | 2.01E-01 ⁱ | 1.20E-02 | 1.97E-04 | 9.00E-05 | 2.56E-06 |
| NICKEL | 7440-02-0 | 2.53E-01 | 2.40E-04 | 2.47E-04 | 2.00E-03 | 5.94E-08 |

METALS:

^aEMISSION RATES ARE BASED ON MEASURED VALUES, EXCEPT WHERE NOTED.
^bBASED ON TABLE OF UNOFFICIAL EPA/PAB UNIT CANCER RISK FACTORS (UCRF), FEBRUARY 1988. UCRF IS DEFINED AS THE PROBABILITY OF CONTRACTING CANCER GIVEN A LIFETIME (~70 YR) EXPOSURE TO 1 UG/M3 OF THE POLLUTANT IN THE ATMOSPHERE.
^cRHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) AS DEFINED BY RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.
^dRHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) APPLICABLE TO FACILITIES DESIGNED TO ACHIEVE LOWEST ACHIEVABLE EMISSION RATE (LAER). RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.
^ePROBABILITY OF CANCER INCIDENCE WITHIN LIFETIME.
^fESTIMATED NUMBER OF CANCER INCIDENTS WITHIN STUDY AREA POPULATION PER YEAR.
^gEMISSION RATE IS BASED ON MINIMUM DETECTION LIMIT FOR NONDETECTED SPECIES OF LITERATURE SOURCES. THIS POLLUTANT WAS NOT TARGETED IN THE CRANSTON TEST PROGRAM.
^hEMISSION RATE IS BASED ON EMISSION MEASUREMENT CONDUCTED AT OTHER SLUDGE INCINERATORS AND REPORTED IN LITERATURE SOURCES. THIS POLLUTANT WAS NOT TARGETED IN THE CRANSTON TEST PROGRAM.
ⁱHEXAVALENT CHROMIUM EMISSION RATES ARE ORDER OF MAGNITUDE-TYPE ESTIMATES BASED ON THE RATIO OF TOTAL CHROMIUM TO HEXAVALENT CHROMIUM IN THE INCOMING SLUDGE.
^jMODELING RESULTS ARE BASED ON MINIMUM ANALYTICAL DETECTION LIMITS AND NOT QUANTIFIED EMISSION RATES. CONCENTRATION AND RISK VALUES THEREFORE REFLECT A WORST-CASE SCENARIO.
^k24 HOUR AAL FOR THIS COMPOUND WITH AND WITHOUT LAER IS 200 UG/M3.

TABLE 4-4. SUMMARY OF HEM MODEL RESULTS - FIELDS POINT FACILITY

| CARCINOGEN POLLUTANT | CAS NO. | EMISSION RATE ^a (G/HR) | UNIT RISK FACTOR ^b | MAXIMUM PREDICTED AAL | | MAXIMUM INDIVIDUAL RISK ^e |
|----------------------------|------------|-----------------------------------|-------------------------------|-----------------------|------------------------------|--------------------------------------|
| | | | | CONCENTRATION (UG/M3) | AVERAGE ^c (UG/M3) | |
| VOCs: | | | | | | |
| ACRYLONITRILE | 107-13-1 | 8.13E+01 | 6.80E-05 | 1.20E-01 | 7.00E-02 | 8.14E-06 |
| BENZENE | 71-43-2 | 1.65E+01 | 8.30E-06 | 2.42E-02 | 1.00E-01 | 2.01E-07 |
| CARBON TETRACHLORIDE | 56-23-5 | 4.54E-02 | 1.50E-05 | 6.68E-05 | 3.00E-01 | 1.00E-09 |
| CHLOROFORM | 67-66-3 | 9.31E-01 | 2.30E-05 | 1.37E+03 | 4.00E-02 | 3.15E-08 |
| 1,2-DICHLOROETHANE | 107-06-2 | 4.54E-02 | 2.60E-05 | 6.68E-05 | 4.00E-01 | 1.74E-09 |
| METHYLENE CHLORIDE | 75-09-2 | 5.49E+00 | 4.70E-07 | 8.09E-03 | 2.00E-01 | 3.80E-09 |
| TETRACHLOROETHENE | 127-18-4 | 3.34E+00 | 5.80E-07 | 4.91E-03 | 5.00E-01 | 2.85E-09 |
| TRICHLOROETHENE | 79-01-6 | 5.65E+00 | 1.30E-06 | 8.32E-03 | 3.00E-01 | 1.08E-08 |
| VINYL CHLORIDE | 75-01-4 | 3.79E+00 | 4.10E-06 | 5.58E-03 | 3.00E-01 | 2.29E-08 |
| BASE COMPOUNDS: | | | | | | |
| BENZO(A)PYRENE | 50-32-8 | 4.99E-02 | 2.30E-03 | 7.35E-05 | | 1.69E-07 |
| BIS(2-ETHYLHEXYL)PHTHALATE | 117-81-7 | 2.31E+00 | 1.30E-07 | 3.41E-03 | 5.00E-01 ⁹ | 4.43E-10 |
| PCBs AND DIOXIN: | | | | | | |
| PCB-1242 | 53469-21-9 | < 1.03E-03 | 1.20E-03 | 1.51E-06 ^f | | 1.81E-09 |
| PCB-1254 | 11097-69-1 | < 1.23E-03 | 1.20E-03 | 1.81E-06 ^f | | 2.17E-09 |
| PCB-1221 | | < 1.03E-03 | 1.20E-03 | 1.51E-06 ^f | | 1.81E-09 |
| PCB-1232 | | < 1.03E-03 | 1.20E-03 | 1.51E-06 ^f | | 1.81E-09 |
| PCB-1248 | | < 1.23E-03 | 1.20E-03 | 1.81E-06 ^f | | 2.17E-09 |
| PCB-1260 | | < 1.23E-03 | 1.20E-03 | 1.81E-06 ^f | | 2.17E-09 |
| PCB-1016 | | < 1.03E-03 | 1.20E-03 | 1.51E-06 ^f | | 1.81E-09 |
| TOTAL PCBs | 1336-36-3 | < 7.80E-03 | 1.20E-03 | 1.15E-05 ^f | | 1.38E-08 |
| 2378 TCDD | 1746-01-6 | 2.19E-04 | 3.30E+01 | 3.23E-07 | | 1.07E-05 |

(Continued)

TABLE 4-4. SUMMARY OF HEM MODEL RESULTS - FIELDS POINT FACILITY

| CARCINOGEN POLLUTANT | CAS NO. | EMISSION RATE ^a (G/HR) | UNIT RISK FACTOR ^b | MAXIMUM PREDICTED AAL ANNUAL CONCENTRATION (UG/M3) | RHODE ISLAND AAL ANNUAL AVERAGE ^c (UG/M3) | RHODE ISLAND AAL W/LAER ANNUAL AVERAGE (UG/M3) | MAXIMUM INDIVIDUAL RISK ^e |
|----------------------|-----------|-----------------------------------|-------------------------------|--|--|--|--------------------------------------|
| ARSENIC | 7440-38-2 | 9.08E-02 | 4.30E-03 | 1.34E-04 | 2.00E-04 | 2.00E-03 | 5.75E-07 |
| BERYLLIUM | 7440-41-7 | < 4.54E-03 | 2.40E-03 | 6.68E-06 ^f | | | 1.60E-08 ^f |
| CADMIUM | 7440-43-9 | 1.89E+00 | 1.80E-03 | 2.77E-03 | 6.00E-04 | 6.00E-03 | 4.99E-06 |
| CHROMIUM VI | 7440-47-3 | 5.58E+00 | 1.20E-02 | 8.22E-03 | 9.00E-05 | 9.00E-04 | 9.87E-05 |
| NICKEL | 7440-02-0 | 2.19E+01 | 2.40E-04 | 3.22E-02 | 2.00E-03 | 2.00E-02 | 7.72E-06 |

METALS:

^aEMISSION RATES ARE BASED ON ESTIMATES. NO EMISSION MEASUREMENTS WERE PERFORMED AT THE FIELDS POINT FACILITY. WITH THE EXCEPTION OF METALS, POLLUTANT EMISSION FACTORS DEVELOPED FOR THE CRANSTON FACILITY WERE ALSO APPLIED TO FIELDS POINT. DEVELOPMENT OF METAL EMISSION FACTOR ESTIMATES IS DESCRIBED IN DETAIL IN APPENDIX B OF THIS DOCUMENT.

^bBASED ON TABLE OF UNOFFICIAL EPA/PAB UNIT CANCER RISK FACTORS (UCRF), FEBRUARY 1988. UCRF IS DEFINED AS THE PROBABILITY OF CONTRACTING CANCER GIVEN A LIFETIME (~70 YR) EXPOSURE TO 1 UG/M3 OF THE POLLUTANT IN THE ATMOSPHERE.

^cRHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) AS DEFINED BY RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.

^dRHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) APPLICABLE TO FACILITIES DESIGNED TO ACHIEVE LOWEST ACHIEVABLE EMISSION RATE (LAER). RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.

^ePROBABILITY OF CANCER INCIDENCE WITHIN LIFETIME.

^fMODELING RESULTS ARE BASED ON MINIMUM ANALYTICAL DETECTION LIMITS FOR NONDETECTED SPECIES OF LITERATURE SOURCES. CONCENTRATION AND RISK VALUES THEREFORE REFLECT A WORST-CASE SCENARIO.

^g24 HOUR AAL FOR THIS COMPOUND WITH AND WITHOUT LAER IS 200 UG/M3.

The following is a summary of significant results:

1. Maximum individual exposure ranges from 5.43×10^{-8} ug/m³ for 2,3,7,8-TCDD to 2.01×10^{-2} ug/m³ for acrylonitrile for the Cranston facility and from 6.22×10^{-8} ug/m³ for 2,3,7,8-TCDD to 1.19×10^{-1} ug/m³ for acrylonitrile for the Fields Point facility.
2. Maximum individual risk ranges from 7.45×10^{-11} for bis(2-ethylhexyl)phthalate to 2.75×10^{-6} for cadmium for the Cranston facility and from 4.43×10^{-10} for bis(2-ethylhexyl)-phthalate to 9.87×10^{-5} for hexavalent chromium for the Fields Point facility.

Maximum individual risk values (the risk parameter which forms the basis for the Rhode Island AALs) for estimated emissions from Cranston and Fields Point are shown in Tables 4-3 and 4-4, respectively. Note that for all listed pollutants, the corresponding risk levels are within ranges considered acceptable by the Rhode Island Department of Environmental Management.

For the Cranston facility (see Table 4-3), the four pollutants that showed the highest associated maximum individual risks were acrylonitrile, dioxin/furans (2,3,7,8-TCDD), cadmium and hexavalent chromium. Of these four pollutants, hexavalent chromium was the only estimated value; others were based on actual measurements. As discussed in Section 5.0 of this document (Engineering Evaluation and Recommendations), strong evidence suggests that acrylonitrile and dioxin/furan emissions from the Cranston incinerator may be largely products of incomplete combustion (PICs) as opposed to being volatilized from incoming sludge feed. Cadmium emissions and associated maximum individual risk levels are due mainly to low cadmium removal efficiencies by the scrubber (~ 50%). This low removal efficiency may be attributed to cadmium being associated with smaller particles that are not effectively removed by wet scrubbers.

For the Fields Point facility (see Table 4-4) the pollutants showing the highest associated maximum individual risks were acrylonitrile, dioxin/furans (2,3,7,8-TCDD), cadmium, hexavalent chromium, and nickel. As discussed in Section 3.0 of this document (Emission Factor Estimates), and reiterated in footnotes to tables, no emission measurements were performed at Fields Point. Generally, pollutant risk values are similar for the two

plants since, in many cases, the Fields Point emission values were based on measurements at Cranston. Nickel emission estimates and risk levels for Fields Point differ from Cranston due primarily to the differences in nickel concentrations in the sludge at the two facilities. Average sludge nickel concentrations at Fields Point during 1986 were approximately 500 ppm (see Table 2-8), whereas average nickel concentration of incoming sludge at Cranston during the October 1987 test was only about 300 ppm (see Table 2-2).

While the numbers in Tables 4-3 and 4-4 assign numbers for exposure and risk to specific chemicals at the two facilities, they are not absolute values. Rather, there are two generally accepted interpretations of these numbers. First, the numbers are intended to be used for comparisons. That is, given a relatively large number of sources and pollutants these estimates of exposure and risk are used to rank the sources and pollutants for regulatory purposes. When ranked by source and pollutant these numbers represent where regulatory resources should be allocated. In this context the numbers are not intended as an estimate of actual exposure and risk expected to occur. The HEM is typically used by EPA to make comparisons among large numbers of pollutants and/or sources. In this particular case, the HEM results may be used to compare potential risks associated with alternative sludge disposal options (e.g., landfill, ocean dumping, land application, etc.).

The second use of these numbers is as estimates of exposure and risk that represent approximate worst case conditions. The modeling approach taken to estimate human exposure and risk contains the following key assumptions:

1. Emission rates used represent a continuous release for a lifetime, that is, seventy years.
2. The distribution of population in the study area is characterized by 1980 residence-based data at the Block Group/Enumeration District level of resolution and remains constant for a lifetime.
3. Individual exposure is experienced only at the geographic location associated with the residence and is computed using ambient air concentrations only.

4. The URFs used represent pollutant-specific risks that EPA characterizes as an upper bound estimate not likely to be less than the actual risk but which may be significantly higher than the actual risk.

These assumptions are important to consider in the exposure and risk assessment procedures because the knowledge and data required to quantify the uncertainty in estimating these quantities is still being developed. Given the procedures currently available to characterize exposure and risk, and the lack of data, very conservative assumptions are often used in exposure/risk analyses. For example, because estimates of less than lifetime risk from exposure to carcinogens are not available, the assumption of lifetime exposure is required.

4.2.2 Noncarcinogen Exposure and Risk

Tables 4-5 and 4-6 contain pollutant-specific data for the following measures:

- emission factor (amount of pollutant per unit of sludge burned),
- emission rate (rate at which pollutant is emitted into atmosphere after incineration),
- maximum individual 24-hour average exposure,
- maximum individual annual average exposure, and
- Rhode Island annual average AAL and AAL with LAER in mg/m^3 per pollutant.

The following is a summary of significant results:

1. Maximum individual annual average exposure ranges from 1.69×10^{-8} ug/m^3 for aldrin to 2.65×10^{-2} ug/m^3 for zinc for the Cranston facility and from 1.00×10^{-7} ug/m^3 for aldrin to 2.96×10^{-1} ug/m^3 for zinc for the Fields Point facility.
2. Maximum individual 24-hour average exposure ranges from 2.77×10^{-7} ug/m^3 for aldrin to 4.35×10^{-1} ug/m^3 for zinc for the Cranston facility and from 2.73×10^{-6} ug/m^3 for aldrin to 9.93 ug/m^3 for lead for the Fields Point facility.

TABLE 4-5. SUMMARY OF ISCST AND ISCLT MODEL RESULTS - CRANSTON FACILITY

| NONCARCINOGEN POLLUTANTS | CAS NO. | EMISSION RATE (G/HR) ^a | EMISSION FACTOR (MG/KG) | RHODE ISLAND AAL | | RHODE ISLAND AAL W/LAER | | MAXIMUM AVERAGE | |
|---------------------------------|------------|-----------------------------------|-------------------------|-------------------------------------|-------------------------------------|-------------------------------|------------------------------|-----------------|--|
| | | | | ANNUAL AVERAGE ^d (UG/M3) | ANNUAL AVERAGE ^e (UG/M3) | 24-HOUR CONCENTRATION (UG/M3) | ANNUAL CONCENTRATION (UG/M3) | | |
| VOCs: | | | | | | | | | |
| ACETONITRILE | 75-05-8 | 6.16E+00 | 1.07E+01 | 7.00E-02 | 7.00E-01 | 9.88E-02 | 6.02E-03 | | |
| BROMOCHLOROMETHANE | 75-27-4 | 8.51E-01 ^b | 1.48E+00 | | | 1.37E-02 | 8.52E-04 | | |
| BROMOMETHANE (METHYL BROMIDE) | 74-83-9 | 2.88E-02 ^b | 5.00E-02 | | | 4.61E-04 | 2.81E-05 | | |
| 2-BUTANONE (MEK) | 78-93-3 | 5.24E+00 | 9.11E+00 | | | 8.40E-02 | 5.12E-03 | | |
| CHLOROBENZENE | 108-90-7 | 5.06E-01 | 8.80E-01 | | | 8.12E-03 | 4.95E-04 | | |
| CHLOROMETHANE (ETHYL CHLORIDE) | 75-00-3 | 4.60E-01 ^b | 8.00E-01 | | | 7.38E-03 | 4.50E-04 | | |
| CHLOROMETHANE (METHYL CHLORIDE) | 74-87-3 | 2.97E+00 | 5.16E+00 | | | 4.76E-02 | 2.90E-03 | | |
| 1,1-DICHLOROETHANE | 75-34-3 | 1.32E-01 ^b | 2.30E-01 | | | 2.12E-03 | 1.29E-04 | | |
| 1,1-DICHLOROETHENE | 75-35-4 | 1.44E-01 | 2.50E-01 | | | 2.31E-03 | 1.41E-04 | | |
| ETHYLBENZENE | 100-41-4 | 1.01E+00 ^b | 1.75E+00 | | | 1.61E-02 | 9.84E-04 | | |
| TOLUENE | 108-88-3 | 3.93E+00 | 6.83E+00 | 4.00E+02 ^g | 4.00E+02 ^g | 6.30E-02 | 3.84E-03 | | |
| 1,1,1-TRICHLOROETHANE | 71-55-6 | 1.05E+00 | 1.82E+00 | | | 1.68E-02 | 1.02E-03 | | |
| XYLENE | 1330-20-7 | 2.32E+00 ^b | 4.04E+00 | h | h | 3.73E-02 | 2.27E-03 | | |
| ACID COMPOUNDS: | | | | | | | | | |
| 2-CHLOROPHENOL | 95-57-8 | < 8.63E-03 ^c | 1.50E-02 | | | 1.38E-04 ^f | 8.43E-06 ^f | | |
| 2,4-DICHLOROPHENOL | 25167-81-1 | < 1.73E-02 ^c | 3.00E-02 | | | 2.77E-04 ^f | 1.69E-05 ^f | | |
| 2,4-DIMETHYLPHENOL | 1300-71-6 | < 1.32E-02 ^c | 2.30E-02 | | | 2.12E-04 ^f | 1.29E-05 ^f | | |
| 2,6-DINITRO-O-CRESOL | 534-52-1 | < 6.84E-02 ^c | 1.19E-01 | | | 1.10E-03 ^f | 6.69E-05 ^f | | |
| 2,4-DINITROPHENOL | 51-28-5 | < 2.96E-01 ^c | 5.15E-01 | | | 4.75E-03 ^f | 2.90E-04 ^f | | |
| 2-NITROPHENOL | 88-75-5 | < 2.20E+00 ^b | 3.82E+00 | | | 3.53E-02 ^f | 2.15E-03 ^f | | |
| 4-NITROPHENOL | 100-02-7 | < 1.64E-01 ^c | 2.85E-01 | | | 2.63E-03 ^f | 1.60E-04 ^f | | |
| P-CHLORO-M-CRESOL | 59-50-7 | < 2.19E-02 ^c | 3.80E-02 | | | 3.51E-04 ^f | 2.14E-05 ^f | | |
| PENTACHLOROPHENOL | 87-86-5 | < 6.90E-02 ^c | 1.20E-01 | | | 1.11E-03 ^f | 6.75E-05 ^f | | |
| PHENOL | 108-75-2 | 1.99E+01 ^b | 3.45E+01 | | | 3.19E-01 ^f | 1.94E-02 ^f | | |
| 2,4,6-TRICHLOROPHENOL | 88-06-2 | < 2.65E-02 ^c | 4.60E-02 | | | 4.24E-04 ^f | 2.59E-05 ^f | | |
| BASE COMPOUNDS: | | | | | | | | | |
| 1,2-DICHLOROBENZENE | 95-50-1 | 6.54E-01 ^b | 1.14E+00 | | | 1.05E-02 | 6.39E-04 | | |
| 1,3-DICHLOROBENZENE | 541-73-1 | 4.97E-01 ^b | 8.64E-01 | | | 7.97E-03 | 4.86E-04 | | |
| 1,4-DICHLOROBENZENE | 106-46-7 | 3.49E+00 ^b | 6.07E+00 | | | 5.60E-02 | 3.41E-03 | | |
| 1,2,4-TRICHLOROBENZENE | 120-82-1 | < 1.38E-02 ^c | 2.40E-02 | | | 2.21E-04 | 1.35E-05 | | |

(Continued)

TABLE 4-5. SUMMARY OF ISCST AND ISCLT MODEL RESULTS - CRANSTON FACILITY

| NONCARCINOGEN POLLUTANTS | CAS NO. | EMISSION RATE ^a (G/HR) | EMISSION FACTOR (MG/KG) | RHODE ISLAND AAL | | MAXIMUM AVERAGE | |
|-----------------------------|-----------|---|-------------------------------|---|---|-------------------------------------|------------------------------------|
| | | | | ANNUAL AVERAGE ^d (UG/M3) | RHODE ISLAND AAL W/LAER ANNUAL AVERAGE ^e (UG/M3) | 24-HOUR CONCENTRATION (UG/M3) | ANNUAL CONCENTRATION (UG/M3) |
| PESTICIDES: | | | | | | | |
| ALDRIN | 309-00-2 | 1.73E-05 | 3.00E-05 | | | 2.77E-07 | 1.69E-08 |
| CHLORODANE | 57-74-9 | 2.60E-04 | 4.52E-04 | | | 4.17E-06 | 2.54E-07 |
| DIELDRIN | 60-57-1 | 2.65E-05 | 4.60E-05 | | | 4.24E-07 | 2.59E-08 |
| METALS: | | | | | | | |
| COPPER ^f | 7440-50-8 | 3.13E+00 | 5.44E+00 | | | 5.02E-02 | 3.06E-03 |
| CHROMIUM ^g | 7440-47-3 | 2.81E+00 | 4.89E+00 | 9.00E-05 | 9.00E-04 | 4.51E-02 | 2.75E-03 |
| LEAD | 7439-92-1 | 1.79E+01 | 3.12E+01 | | | 2.88E-01 | 1.75E-02 |
| SELENIUM ^h | 7752-49-2 | 7.99E-01 | 1.39E+00 | | | 1.28E-02 | 7.81E-04 |
| ZINC ⁱ | 7440-66-6 | 2.71E+01 | 4.72E+01 | | | 4.35E-01 | 2.65E-02 |

^a EMISSION RATES ARE BASED ON MEASURED VALUES EXCEPT WHERE NOTED.

^b EMISSION RATE IS BASED ON EMISSION MEASUREMENTS CONDUCTED AT OTHER SLUDGE INCINERATORS AND REPORTED IN LITERATURE SOURCES.

^c THIS POLLUTANT WAS NOT TARGETED IN THE CRANSTON TEST PROGRAM.

^d EMISSION RATE IS BASED ON MINIMUM DETECTION LIMIT FOR NONDETECTED SPECIES OF LITERATURE SOURCES. THIS POLLUTANT WAS NOT TARGETED IN THE CRANSTON TEST PROGRAM.

^e RHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) AS DEFINED BY RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.

^f RHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) APPLICABLE TO FACILITIES DESIGNED TO ACHIEVE LOWEST ACHIEVABLE EMISSION RATE (LAER).

^g RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.

^h MODELING RESULTS ARE BASED ON MINIMUM ANALYTICAL DETECTION LIMITS AND NOT QUANTIFIED EMISSION RATES. CONCENTRATION LEVELS THEREFORE REFLECT A WORST-CASE SCENARIO.

ⁱ 24 HOUR AVERAGE AAL FOR TOLUENE WITH AND WITHOUT LAER IS 2000.

^j 24 HOUR AVERAGE AAL FOR XYLENE WITH AND WITHOUT LAER IS 700.

^k 24 HOUR AVERAGE GUIDELINE LEVEL FOR COPPER = 0.2, FOR CHROMIUM = .04, SELENIUM = 1, AND ZINC = 200 UG/M3.

TABLE 4-6. SUMMARY OF ISCST AND ISCLT MODEL RESULTS - FIELDS POINT FACILITY

| NONCARCINOGEN POLLUTANTS | CAS NO. | EMISSION RATE ^a (G/HR) | EMISSION FACTOR (MG/KG) | RHODE ISLAND | | MAXIMUM AVERAGE | |
|---------------------------------|------------|---|-------------------------------|---|---|-------------------------------------|------------------------------------|
| | | | | ANNUAL AVERAGE ^b (UG/M3) | RHODE ISLAND AAL W/LAER ANNUAL AVERAGE ^c (UG/M3) | 24-HOUR CONCENTRATION (UG/M3) | ANNUAL CONCENTRATION (UG/M3) |
| VOCS: | | | | | | | |
| ACETONITRILE | 75-05-8 | 2.43E+01 | 1.07E+01 | 7.00E-02 | 7.00E-01 | 9.74E-01 | 3.58E-02 |
| BROMOCHLOROMETHANE | 75-27-4 | 3.36E+00 | 1.48E+00 | | | 1.35E-01 | 4.95E-03 |
| BROMOMETHANE (METHYL BROMIDE) | 74-83-9 | 1.14E-01 | 5.00E-02 | | | 4.55E-03 | 1.67E-04 |
| 2-BUTANONE (MEK) | 78-93-3 | 2.07E+01 | 9.11E+00 | | | 8.29E-01 | 3.04E-02 |
| CHLOROBENZENE | 108-90-7 | 2.00E+00 | 8.80E-01 | | | 8.00E-02 | 2.94E-03 |
| CHLOROETHANE (ETHYL CHLORIDE) | 75-00-3 | 1.82E+00 | 8.00E-01 | | | 7.28E-02 | 2.67E-03 |
| CHLOROMETHANE (METHYL CHLORIDE) | 74-87-3 | 1.17E+01 | 5.16E+00 | | | 4.69E-01 | 1.72E-02 |
| 1,1-DICHLOROETHANE | 75-34-3 | 5.22E-01 | 2.30E-01 | | | 2.09E-02 | 7.69E-04 |
| 1,1-DICHLOROETHENE | 75-35-4 | 5.68E-01 | 2.50E-01 | | | 2.27E-02 | 8.35E-04 |
| ETHYLBENZENE | 100-41-4 | 3.97E+00 | 1.75E+01 | | | 1.59E-01 | 5.85E-03 |
| TOLUENE | 108-88-3 | 1.55E+01 | 6.83E+00 | 4.00E+02 ^e | 4.00E+02 ^e | 6.21E-01 | 2.28E-02 |
| 1,1,1-TRICHLOROETHANE | 71-55-6 | 4.13E+00 | 1.82E+00 | | | 1.66E-01 | 6.08E-03 |
| XYLENE | 1330-20-7 | 9.17E+00 | 4.04E+00 | f | f | 3.67E-01 | 1.35E-02 |
| ACID COMPOUNDS: | | | | | | | |
| 2-CHLOROPHENOL | 95-57-8 | <3.41E-02 | 1.50E-02 | | | 1.36E-03 ^d | 5.01E-05 ^d |
| 2,4-DICHLOROPHENOL | 25167-81-1 | <6.81E-02 | 3.00E-02 | | | 2.73E-03 ^d | 1.00E-04 ^d |
| 2,4-DIMETHYLPHENOL | 1300-71-6 | <5.22E-02 | 2.30E-02 | | | 2.09E-03 ^d | 7.69E-05 ^d |
| 2,6-DINITRO-O-CRESOL | 534-52-1 | <2.70E-01 | 1.19E-01 | | | 1.08E-02 ^d | 3.98E-04 ^d |
| 2,4-DINITROPHENOL | 51-28-5 | <1.17E+00 | 5.15E-01 | | | 4.68E-02 ^d | 1.72E-03 ^d |
| 2-NITROPHENOL | 88-75-5 | 8.67E+00 | 3.82E+00 | | | 3.48E-01 | 1.28E-02 |
| 4-NITROPHENOL | 100-02-7 | <6.47E-01 | 2.85E-01 | | | 2.59E-02 ^d | 9.52E-04 ^d |
| P-CHLORO-M-CRESOL | 59-50-7 | <8.63E-02 | 3.80E-02 | | | 3.46E-03 ^d | 1.27E-04 ^d |
| PENTACHLOROPHENOL | 87-86-5 | <2.72E-01 | 1.20E-01 | | | 1.09E-02 ^d | 4.01E-04 ^d |
| PHENOL | 108-75-2 | 7.84E+01 | 3.45E+01 | | | 3.14E+00 | 1.15E-01 |
| 2,4,6-TRICHLOROPHENOL | 88-06-2 | <1.04E-01 | 4.60E-02 | | | 4.18E-03 ^d | 1.54E-04 ^d |
| BASE COMPOUNDS: | | | | | | | |
| 1,2-DICHLOROBENZENE | 95-50-1 | 2.58E+00 | 1.14E+00 | | | 1.03E-01 | 3.80E-03 |
| 1,3-DICHLOROBENZENE | 541-73-1 | 1.96E+00 | 8.64E-01 | | | 7.86E-02 | 2.89E-03 |
| 1,4-DICHLOROBENZENE | 106-46-7 | 1.38E+01 | 6.07E+00 | | | 5.52E-01 | 2.03E-02 |
| 1,2,4-TRICHLOROBENZENE | 120-82-1 | <5.45E-02 | 2.40E-02 | | | 2.18E-03 ^d | 8.02E-05 ^d |

(Continued)

TABLE 4-6. SUMMARY OF ISCST AND ISCMT MODEL RESULTS - FIELDS POINT FACILITY

| NONCARCINOGEN POLLUTANTS | CAS NO. | EMISSION RATE ^a (G/HR) | EMISSION FACTOR (MG/KG) | RHODE ISLAND AAL | | RHODE ISLAND AAL W/LAER | | MAXIMUM AVERAGE | |
|-----------------------------|-----------|---|-------------------------------|---|---|-------------------------------------|------------------------------------|-----------------|----------|
| | | | | ANNUAL AVERAGE ^b (UG/M3) | ANNUAL AVERAGE ^c (UG/M3) | 24-HOUR CONCENTRATION (UG/M3) | ANNUAL CONCENTRATION (UG/M3) | | |
| PESTICIDES: | | | | | | | | | |
| ALDRIN | 309-00-2 | 6.81E-05 | 3.00E-05 | | | | | 2.73E-06 | 1.00E-07 |
| CHLORODANE | 57-74-9 | 1.03E-03 | 4.52E-04 | | | | | 4.11E-05 | 1.51E-06 |
| DIELDRIN | 60-57-1 | 1.04E-04 | 4.60E-05 | | | | | 4.18E-06 | 1.54E-07 |
| METALS: | | | | | | | | | |
| COPPER | 7440-50-8 | 1.41E+02 | 6.20E+01 | | | | | 5.64E+00 | 2.07E-01 |
| CHROMIUM | 7440-47-3 | 2.24E+01 | 9.85E+00 | | | | | 8.96E-01 | 3.29E-02 |
| LEAD | 7439-92-1 | 2.48E+01 | 1.09E+01 | 9.00E-05 | 9.00E-04 | | | 9.93E-01 | 3.65E-02 |
| SELENIUM | 7752-49-2 | 3.16E+00 | 1.39E+00 | | | | | 1.26E-01 | 4.65E-03 |
| ZINC | 7440-66-6 | 2.01E+02 | 8.87E+01 | | | | | 8.07E+00 | 2.96E-01 |

^a EMISSION RATES ARE BASED ON ESTIMATES. NO EMISSION MEASUREMENTS WERE PERFORMED AT THE FIELDS POINT FACILITY. WITH THE EXCEPTION OF METALS, EMISSION FACTORS DEVELOPED FOR THE CRANSTON FACILITY WERE ALSO APPLIED TO FIELDS POINT. DEVELOPMENT OF METAL EMISSION FACTOR ESTIMATES IS DESCRIBED IN DETAIL IN APPENDIX B OF THIS DOCUMENT.

^b RHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) AS DEFINED BY RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.

^c RHODE ISLAND ACCEPTABLE AMBIENT LEVEL (AAL) APPLICABLE TO FACILITIES DESIGNED TO ACHIEVE LOWEST ACHIEVABLE EMISSION RATE (LAER). RHODE ISLAND AIR POLLUTION CONTROL REGULATION NO. 22, MARCH 1988.

^d MODELING RESULTS ARE BASED ON MINIMUM ANALYTICAL DETECTION LIMITS FOR NONDETECTED SPECIES OF LITERATURE SOURCES. CONCENTRATION LEVELS THEREFORE REFLECT A WORST-CASE SCENARIO.

^e 24 HOUR AAL FOR TOLUENE WITH AND WITHOUT LAER IS 2000 UG/M3.

^f 24 HOUR AAL FOR XYLENE WITH AND WITHOUT LAER IS 700 UG/M3.

Rhode Island has adopted the AAL values included in the Rhode Island Air Pollution Control Regulation No. 22 as allowable exposure levels. The derivation of the Rhode Island AAL is discussed in Section 4.2.1. Exposure levels above the AAL are considered unacceptable based on the health effects associated with exposure to the toxic substance.

5.0 ENGINEERING EVALUATION AND RECOMMENDATIONS

Emissions from sewage sludge incinerators are affected by the design of the incinerator, the type and design of the control device used, the characteristics of the sludge being burned, as well as the method of operation of the incinerator and control device.

The major variable affecting particulate as well as particulate-bound metal and particulate-bound organic emissions is the operating pressure drop of the wet scrubbing system. The particulate removal efficiency of a given wet scrubber increases as the pressure drop of the scrubber increases. Removal efficiency of particle-bound metals and particle-bound organics also increases with increasing pressure drop, although the magnitude of these emissions and particulate emissions differ due to their relative size distributions. The single most effective means of minimizing particulate, particulate-bound metal and particulate-bound organic emissions is to continuously operate the scrubber system at the maximum pressure drop conditions.

The major variable affecting organic emissions is the operating temperatures of the incinerator and the external afterburner. Organic emissions from sludge incineration occur primarily by two mechanisms. The first is volatilization of organic constituents contained in the sludge during drying, the second is the formation of products of incomplete combustion (PIC) through pyrosynthesis. This second mechanism involves the combination of carbon and hydrogen atoms at elevated temperatures by means of free-radical paths. Chemical mass balances performed during analysis of the Cranston test data strongly support this second mechanism (PIC) as being a major mechanism by which many target species are formed.³⁸ For example, mass flow rates of benzene, acetonitrile, vinyl chloride, and acrylonitrile measured in the incinerator offgases are between 20 and 300 times larger than the mass flow of these compounds entering the system from the sludge and scrubber water. Similarly, dioxin/furan emission rates (2,3,7,8 toxic equivalents) measured in the controlled offgases are approximately 10 times larger than the mass flow entering the system from the sludge.

The primary means of minimizing emissions of organics from sludge incinerators is to maintain temperatures of 1400°F to 1700°F in the combustion zone along with sufficient quantities of excess air. Maintaining these temperatures requires the use of auxiliary fuel in most cases. Such temperatures along with good mixing and sufficient residence times are capable of oxidizing organic compounds to CO₂ and water. Maintaining temperatures in the range of 1400-1800°F in the afterburner along with oxygen contents of ~ 6 to 8 percent allows the destruction of organics volatilized from the sludge feed. Finally, organic emissions may also occur as a result of using plant influent water as scrubber feed. In such cases, volatile organics may be stripped from the untreated water and emitted. Use of plant effluent water for operating the scrubber will minimize these potential emissions.

Specific recommendations for applying these principles at each of the two Rhode Island incinerators are discussed in the following subsections.

5.1 CRANSTON

No historical records were available for evaluating the scrubber operation practices at the Cranston facility since the incinerator had only recently begun operation. However, based on an on-site inspection of the pollution control system conducted during early stages of this project, the scrubber system is judged to be capable of achieving and maintaining good emission reduction of particulate and particulate bound metal emissions. This conclusion is based on design of the scrubber and the presence of the automatic variable throat damper system. The venturi damper is automatically controlled so that scrubber pressure drop can be continuously maintained at optimal conditions despite changes in the flue gas flow characteristics. The effectiveness of the Cranston scrubber system was demonstrated during the October 1987 test series. These data are shown in Table 5-1. Note that particulate removal efficiency of the scrubber system averaged 97 percent. Note also that reduction in metal emissions also occurred with removal efficiencies ranging from 37 percent for lead, to

TABLE 5-1. CONTROL DEVICE EFFICIENCY FOR METALS AND PARTICULATE FOR CRANSTON

| Metal | Metal Mass Flow Rate at the Control Device Inlet (mg/hr) | | | Metal Mass Emission Rate at the Control Device Outlet (mg/hr) | | | | Control Device Emission Removal Efficiency (%) | | | | |
|-------------|--|--------|--------|---|-----------------|-----------------|-----------------|--|--------|--------|--------|---------|
| | Run 08 | Run 09 | Run 10 | Average | Run 08 | Run 09 | Run 10 | Average | Run 08 | Run 09 | Run 10 | Average |
| | | | | | | | | | | | | |
| Arsenic | 192 | 145 | 146 | 161 | 2 ^a | 4 | 2 ^a | 3 | 99.1 | 97.2 | 98.8 | 98.4 |
| Beryllium | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA | NA | NA |
| Cadmium | 3071 | 3466 | 2888 | 3142 | 1370 | 1720 | 1814 | 1635 | 55.4 | 50.4 | 37.2 | 47.7 |
| Chromium | 4159 | 1949 | 3348 | 3152 | 20 ^b | 20 ^b | 20 ^b | 20 ^b | 95.5 | 99.0 | 99.4 | 99.3 |
| Lead | 47988 | 33798 | 29849 | 37212 | 15481 | 20223 | 28819 | 21508 | 67.7 | 40.2 | 3.5 | 37.1 |
| Nickel | 2338 | 4779 | 3378 | 3498 | 107 | 196 | 157 | 153 | 95.4 | 95.9 | 95.4 | 95.6 |
| Particulate | 27.8 | 21.4 | 21.5 | 23.6 | 0.85 | 0.69 | 0.55 | 0.70 | 96.9 | 96.8 | 97.4 | 97.1 |

^aThe minimum detection limit was used to calculate an emission removal efficiency for Arsenic.

^bThe average of the total chromium results determined from the Hexavalent Chromium trains was used to calculate the removal efficiency for chromium.

99 percent for chromium (lower removal efficiencies for metals are expected since particle bound metals are predominately associated with smaller diameter particles and since some fraction of the metal being emitted is generally assumed to be in the vapor phase).

Changes to the existing scrubber system or operational practices at the Cranston facility are not recommended. Particulate and particulate bound emissions can continue to be minimized by continuing to monitor the operation of the automatic variable throat damper and the corresponding scrubber Δp .

Organic emissions at the Cranston facility can be minimized by maintaining combustion zone temperatures of approximately 1400^oF or greater, and by operating the external afterburner as designed. Table 5-2 contains a summary of furnace and afterburner temperatures recorded during the inlet VOST test runs at the Cranston incinerator. Note that three different furnace/afterburner conditions were tested. These are characterized as normal operation (runs 01-03), hot furnace/no afterburner (runs 07-09), and hot furnace with afterburner (runs 04-06).

The effect of furnace temperature and afterburner use is demonstrated clearly by results in Tables 5-3 and 5-4. Table 5-3 shows the continuous emission monitor averages for each of the three sets of furnace/afterburner operating conditions. Dramatic reductions in carbon monoxide and total hydrocarbon emissions occur when furnace temperatures remain hot and the external afterburner is used (runs 04-06). Table 5-4 also shows similar reductions for volatile organic emissions under these conditions.

In addition to showing the effect of the afterburner, the data in Table 5-4 provides insight into some of the causal factors that influence organic emissions from sludge incinerators, specifically furnace temperature. As seen in the table, flue gas measurements for each detected compound are dramatically higher when furnace temperatures are low (normal operation). These data combined with the mass balance analysis described earlier in this section support the conclusion that PIC information may be a major cause of organic emissions under normal operating conditions.

TABLE 5-2. SUMMARY OF FURNACE AND AFTERBURNER TEMPERATURES AND OPERATING CONDITIONS DURING THE INLET VOST TESTS AT CRANSTON

| | Average Run 01-03 Normal Operation | Average Run 07-09 Hot Furnace No Afterburner | Average Run 04-06 Hot Furnace Hot Afterburner |
|----------------------------|---|---|--|
| Hearth #1 °F | 844 | 919 | 972 |
| Hearth #2 °F | 1213 | 1484 | 1424 |
| Hearth #3 °F | 1378 | 1649 | 1590 |
| Hearth #4 °F | 1219 | 1235 | 1153 |
| Hearth #5 °F | 1021 | 844 | 856 |
| Afterburner Temperature °F | 906 | 1264 | 1374 |
| Venturi Δp | 19.4 | 20.6 | 23.1 |

TABLE 5-3. COMPARISON OF DIFFERENT FURNACE AND AFTERBURNER OPERATING CONDITIONS ON CARBON MONOXIDE AND TOTAL HYDROCARBON EMISSIONS

| Parameter | Average Run 01-03 Normal Operation | Average Run 04-06 Hot Furnace Hot Afterburner |
|----------------------|---|--|
| O ₂ ppmV | 10.97 | 11.21 |
| CO ₂ ppmV | 6.94 | 9.80 |
| CO ppmV | 1200 | 190 |
| THC ppmV | 13.4 | 1.21 |

TABLE 5-4. COMPARISON OF DIFFERENT FURNACE AND AFTERBURNER OPERATING CONDITIONS ON VOLATILE ORGANIC MASS FLOW RATES AT THE INLET TO THE SCRUBBER - CRANSTON

| Compound | Flue Gas Inlet (mg/hr) | | |
|--------------------------|--|--|---|
| | Average ^a Run 01-03 Normal Operation | Average ^a Run 07-09 Hot Furnace No Afterburner | Average ^a Run 04-06 Hot Furnace Hot Afterburner |
| Acetonitrile | 60,625 ^b | 3,615 | 881 |
| Acrylonitrile | 30,728 | 11,534 | 1,625 ^b |
| Benzene | 5,683 | 817 | 449 |
| 2-Butanone (MEK) | 7,854 | ND ^c | 54.4 |
| Carbon Tetrachloride | 25.5 ^b | 22.5 | 4.71 |
| Chlorobenzene | 1,077 | 57.7 | 21.7 ^b |
| Chloroform | 94.6 ^b | 33.6 | 13.8 |
| 1,2-Dichloroethane | ND ^c | ND ^c | ND ^c |
| Trans-1,2-Dichloroethene | ND ^c | ND ^c | ND ^c |
| Ethylbenzene | 1,635 | ND ^c | 63.1 |
| Methylene Chloride | 91.0 | 13.8 | 13.1 |
| Pyridine | ND ^c | ND ^c | ND ^c |
| Tetrachloroethene | 947 | 50 | 1.78 |
| Toluene | 3,512 | 62.7 | 330 |
| 1,1,1-Trichloroethane | 50.5 | 36.5 | 5.06 |
| Trichloroethene | 290 | 41.5 | 2.47 |
| Vinyl Chloride | 3,106 | ND ^c | ND ^c |

^aFurnace and afterburner temperatures and conditions are delineated in Table 5-2.

^bBased on the average of two runs.

^cND = Not detected.

Based on these data and observations during on-site visits, recommendations on ways to minimize organic emissions for the Cranston plant include:

- Continue to use the auxiliary afterburner on a routine basis, adhering closely to the temperature, oxygen, and residence time design requirements.
- Maintain "hot" furnace conditions so that combustion zone temperatures exceed 1400^oF.
- Use auxiliary fuel to maintain desired furnace and afterburner temperatures. Autogeneous burning of Cranston sludge will not achieve and maintain sufficient temperatures to optimize reduction of organic emissions.
- Implement a routine maintenance schedule. Episodic emissions often occur as a result of equipment failure. Routine maintenance should include incinerator controls, burners, dampers, and monitoring devices as well as scrubbers, pumps, and sludge dewatering presses. For example, during the October 1987 emission test the oxygen monitors located in the incinerator exhaust stream were not functioning properly. This malfunction affected the amount of combustion air introduced into the incinerator since the monitoring devices automatically controlled the air inlet damper. Installation of a blow back system within the O₂ sampling lines would eliminate plugging problems, which are the cause of erroneous O₂ readings. Other maintenance related items observed while on-site include the "sticking" of the sludge feed door in the open position. The sludge feed door should be dampered such that the amount of excess ambient air drawn into the furnace is minimized. In the open position, ambient air cools the exhaust, severely affecting temperatures in the afterburner thereby resulting in poor organic reduction.
- Minimize the occurrence of transient operation such as start-up, shut-down, temperature excursions, feed rate changes, feed interruption, etc. Air emissions under transient conditions may be significantly higher than those emissions when the furnace is operating under steady-state conditions. Practical ways to minimize transient operation include 24-hour per day, 7 day per week operation, scheduled shut-downs for periodic maintenance, and the use of trained, experienced furnace operators.

5.2 FIELDS POINT

Since the Fields Point incinerator was not operating at the time of this study, recommendations for minimizing emissions are based on historical records and an on-site equipment evaluation. Therefore, emission estimates presented in Section 3.0 and the engineering evaluation and recommendations presented in this section do not reflect any upgrades or modifications that may be planned as part of future renovations. Daily operating records for the most recent period (July 1982) of operation were reviewed and a summary of these records is presented in Table 5-5. As seen in the table, sludge feed was interrupted frequently, and the feed rates varied considerably from hour to hour and day to day. Interruptions in sludge feed were the result of equipment failures. These failures occurred in either the sludge conveying system which transports sludge from the dewatering presses to the incinerator, or in the filter presses. Frequent interruptions to sludge feed causes wide variations in incinerator temperatures, excess air, and exhaust gas flow rates thereby adversely affecting the performance of the scrubber system.

These operating records, also seen in Table 5-5, demonstrate that incinerator temperatures rarely achieved (less than 10% of the operating time) 1400⁰F in the combustion zone. Further, since records did not contain data on afterburner temperatures and other operating parameters, the conclusion is drawn that the afterburner was not routinely used. Operating records also showed that the pressure drop across the scrubber varied widely, with frequent periods in which the scrubber was ineffective. Although the scrubber is designed to achieve pressure drops on the order of 40 in. W.G., the operating records indicate that the system was operated at a significantly lower pressure drop about 80 percent of the time. Table 5-6 summarizes the percentage of time in which the scrubber system was operated in each of four pressure drop ranges.

On-site inspections of the scrubber system revealed apparent reasons for difficulties in maintaining sufficient pressure drop. First, the degree of convergence of the scrubber throat area was limited. Dimensions for the venturi section were not available, but visual inspection indicated that the

TABLE 5-5. SUMMARY OF INCINERATOR AND SCRUBBER OPERATING PARAMETERS, FIELDS POINT SEWAGE SLUDGE INCINERATOR, JULY 1982

| Date | Sludge Charge | | Hours per Day Sludge Charged | Hearth #1 | | Hearth #4 | | Hearth #5 | | Hearth #6 | | Number of Hours per Day 1400° F Achieved | Scrubbing System | | |
|---------|-----------------------------|-----|---------------------------------|----------------------|-----|----------------------|------|----------------------|------|----------------------|-----|---|---------------------|------|-----|
| | Rate Range (Wet Tons/Hr) | Low | | Temp. Range (° F) | | Temp. Range (° F) | | Temp. Range (° F) | | Temp. Range (° F) | | | in. W.G. | High | Low |
| | | | | High | Low | High | Low | High | Low | High | Low | | | | |
| 7-2-82 | 4.0 | 0.8 | 15 | 1050 | 610 | 1520 | 960 | 1090 | 980 | 950 | 580 | 3 | 41.2 | 11.0 | |
| 7-3-82 | 4.0 | 2.0 | 24 | 850 | 600 | 1220 | 810 | 1120 | 920 | 1040 | 680 | 0 | 43.2 | 14.6 | |
| 7-4-82 | 4.5 | 1.2 | 21 | 960 | 600 | 1400 | 870 | 1200 | 920 | 1150 | 530 | 1 | 35.8 | 23.8 | |
| 7-5-82 | 4.5 | 0.3 | 23 | 870 | 520 | 1320 | 740 | 1300 | 900 | 1030 | 710 | 0 | 41.6 | 0 | |
| 7-9-82 | 6.5 | 0 | 5 | 700 | 680 | 1100 | 1000 | 1520 | 1300 | 1520 | 780 | 3 | 23.3 | 0 | |
| 7-11-82 | a | a | a | 1110 | 670 | 1710 | 1050 | 1460 | 1020 | 1620 | 910 | 9 | 17.6 | 0 | |
| 7-13-82 | a | a | a | 790 | 550 | 2020 | 800 | 2030 | 850 | 1500 | 510 | 2 | 42.6 | 0 | |
| 7-15-82 | 8.0 | 1.2 | 18 | 800 | 510 | 1050 | 640 | 1400 | 580 | 1400 | 650 | 1 | 35.3 | 0 | |
| 7-16-82 | 7.0 | 2.0 | 24 | 650 | 510 | 1020 | 550 | 1270 | 590 | 1450 | 680 | 2 | 37.2 | 28.8 | |
| 7-17-82 | 5.0 | 0.5 | 23 | 820 | 550 | 1000 | 820 | 1200 | 830 | 1420 | 620 | 1 | 38.1 | 0 | |
| 7-19-82 | 7.6 | 0.8 | 20 | 760 | 560 | 1140 | 710 | 1340 | 800 | 1420 | 730 | 2 | 43.0 | 0 | |
| 7-21-82 | 8.0 | 1.0 | 22 | 770 | 530 | 1000 | 760 | 1480 | 830 | 1630 | 720 | 2 | 43.8 | 10.9 | |
| 7-22-82 | 10.6 | 3.0 | 20 | 780 | 540 | 1140 | 710 | 1440 | 930 | 1600 | 780 | 5 | 43.2 | 14.0 | |
| 7-23-82 | 7.1 | 2.9 | 24 | 820 | 550 | 1210 | 810 | 1180 | 920 | 1180 | 720 | 0 | 31.3 | 19.2 | |
| 7-24-82 | 6.0 | 4.0 | 24 | 800 | 510 | 1030 | 800 | 1380 | 820 | 1580 | 620 | 2 | 30.2 | 23.0 | |
| 7-25-82 | 5.7 | 0.3 | 18 | 960 | 520 | 1140 | 760 | 1280 | 1140 | 1050 | 620 | 0 | 35.5 | 0 | |
| 7-26-82 | 6.1 | 1.7 | 24 | 850 | 540 | 1030 | 800 | 1340 | 1120 | 1500 | 620 | 2 | 30.9 | 22.3 | |
| 7-27-82 | 5.1 | 1.4 | 18 | 680 | 520 | 960 | 790 | 1150 | 890 | 1100 | 470 | 0 | 35.4 | 23.5 | |
| 7-28-82 | 7.7 | 2.9 | 24 | 980 | 520 | 1250 | 760 | 1300 | 970 | 1400 | 600 | 1 | 35.6 | 22.8 | |
| 7-29-82 | 6.8 | 0.8 | 15 | 810 | 540 | 1160 | 850 | 1240 | 1080 | 1270 | 770 | 0 | 36.0 | 0 | |
| 7-30-82 | 6.1 | 3.2 | 10 | 700 | 490 | 1050 | 730 | 1230 | 860 | 1300 | 650 | 0 | 32.0 | 20.8 | |
| 7-31-82 | 5.6 | 3.8 | 6 | 700 | 610 | 1090 | 890 | 1270 | 1060 | 1330 | 980 | 0 | 28.0 | 23.0 | |

^a Sludge scale and meter not operating.

area ratio between the inlet and the throat was much smaller (less convergent) than a typical venturi scrubber (ratio of ~ 4:1). Further, a manually operated damper was the primary mechanism by which scrubber pressure drop was maintained. These two design limitations, combined with the lack of remote pressure drop monitoring capabilities, are judged to be significant obstacles to maintaining continuous emission reduction. Emission factors, developed and presented in Section 3.0 of this document, consider and reflect these operational and design factors.

The following are specific recommendations for minimizing emissions at the Fields Point facility.

- Replace the existing scrubber system. Inspection of the system and review of the operating records together confirm that the scrubber system is inadequate to provide optimal emission control. The scrubber pressure drop should be continuously monitored and the damper and liquid injection rate automatically controlled. Such a system will eliminate periods of inadequate emission reduction as evidenced by previous operating practices (see Table 5-6).
- Maintain "hot" furnace conditions so that combustion zone temperatures exceed 1400°F. Continue to use auxiliary fuel to maintain appropriate temperatures.
- Operate the external afterburner at designed temperatures and flow rates to optimize organic reduction.
- Improve the dewatering presses and sludge conveying system to minimize sludge feed interruptions.
- Implement a routine maintenance schedule including incinerator controls, burners, dampers, and monitoring devices, etc.

TABLE 5-6. FIELDS POINT SCRUBBER SYSTEM OPERATING SUMMARY: HOURS PER DAY THE SCRUBBER SYSTEM WAS OPERATED IN EACH OF FOUR PRESSURE DROP RANGES, JULY 1982

| Date | ΔP in. H ₂ O Gauge | | | |
|---|---------------------------------------|--------|-----------|-----------|
| | 0 - 5 | 5 - 19 | 19.1 - 31 | 31.1 - 49 |
| 7-2-82 | | 1 | 11 | 3 |
| 7-3-82 | | 3 | 17 | 4 |
| 7-4-82 | | | 13 | 6 |
| 7-5-82 | 12 | | 6 | 6 |
| 7-9-82 | | | 1 | 1 |
| 7-10-82 | 3 | 3 | 11 | 6 |
| 7-13-82 | 2 | 2 | 14 | 6 |
| 7-15-82 | 1 | | 12 | 5 |
| 7-16-82 | | | 4 | 20 |
| 7-17-82 | 3 | 4 | 11 | 3 |
| 7-19-82 | 3 | 2 | 11 | 4 |
| 7-20-82 | | 9 | 14 | |
| 7-21-82 | 1 | 15 | 4 | 4 |
| 7-22-82 | | 3 | 8 | 9 |
| 7-23-82 | | 1 | 22 | 1 |
| 7-24-82 | | | 24 | |
| 7-25-82 | | | 13 | 1 |
| 7-26-82 | | | 24 | |
| 7-27-82 | 1 | | 15 | 2 |
| 7-28-82 | | | 21 | 3 |
| 7-29-82 | | | 9 | 4 |
| 7-30-82 | | 1 | 8 | 2 |
| 7-31-82 | | | 6 | |
| | 26 hrs | 44 hrs | 279 hrs | 90 hrs |
| Percent of Operating Time in Each Range | 5.9% | 10.0% | 63.6% | 20.5% |

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APPENDIX A
RESULTS FROM THE OCTOBER 1987 TEST PROGRAM AT
CRANSTON, RHODE ISLAND

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RESULTS FROM THE OCTOBER 1987 TEST PROGRAM AT
CRANSTON, RHODE ISLAND

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A.1 PRELIMINARY VOLATILE ORGANIC EMISSION RESULTS, DECEMBER 8, 1987

RADIAN

CORPORATION

December 8, 1987

Dr. Harry Bostian
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
26 West St. Clair Street
Cincinnati, Ohio 45268

Dear Harry:

Enclosed are the preliminary volatile results from the fourth Sewage Sludge Test at Cranston, R.I. A total of 15 VOST runs were conducted during the test (9 at the control device inlet and 6 at the control device outlet). Three different process operating conditions were evaluated for volatile emissions. Runs 01-03 were conducted under normal operating conditions. Sludge incineration was primarily autogenous and combustion hearth temperatures were approximately 1400°F. During Runs 04-09 the combustion hearth temperature was maintained near or above 1600°F using auxiliary burners in the furnace. An auxiliary afterburner located at the furnace exit was also used during Runs 04-06. Simultaneous VOST sampling at the control device inlet and outlet was conducted during the first 6 runs (01-06). During the last three runs (07-09) VOST sampling was only conducted at the control device inlet.

The results are presented in the attached tables. It should be noted that many of the target volatile compounds were saturated, therefore the results presented in the tables represent a minimum estimate of actual concentrations present. The VOST results from the control device inlet are shown in Tables 1 through 3 while the outlet VOST results are presented in Tables 4 through 6. The raw analytical results for each individual pair of traps (ng per trap) are shown as well as the flue gas concentration (ug/dscm) and the mass flow rate (mg/hr). In addition, the results of the process sample analyses are presented in Tables 7 through 10. The sludge feed volatile concentration (ug/kg) and target volatile feed rate (mg/hr) are shown in Tables 7 and 8, respectively. The results of the scrubber influent water analyses are shown in Tables 9 and 10.

Some of the major conclusions from these results include:

- 1) The mass flow rates of the target volatile organic compounds at the control device inlet and outlet were drastically reduced during the runs where the combustion hearth was kept at an elevated temperature and the afterburner was used.
- 2) Acetonitrile, acrylonitrile, 2-butanone, benzene and toluene were the most prominent emissions when the incinerator was operated under normal operating conditions. When the incinerator was operated at the elevated temperature, trichloroethene and 1,1,1-trichloroethane were the prominent volatile organic emissions.

- 3) Nine of the target volatile organic compounds were detected in the sludge feed samples. The major constituents were; toluene, tetrachloroethane, trichloroethene, and methylene chloride.
- 4) Six of the target volatile organic compounds were detected in the scrubber influent water. The major constituents were methylene chloride, tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane.

If you have any questions or comments concerning the VOST results please contact me at (919) 481-0212.

Sincerely,

Dennis R. Knisley
Chemical Engineer

DRK/ljs

cc: Gene Crumpler, EPA
Bob Dykes, Radian
Keith Barnett, Radian

Attachments

TABLE 1 - RAW ANALYTICAL DATA FOR THE VOLATILE ORGANICS CAPTURED IN THE INLET SAMPLE TRAINS

| COMPOUND | RUN 01 | | | | | | | RUN 02 | | | | | | | RUN 03 | | | | | | | | |
|--------------------------|--------|-------|-------|-------|-------|-------|-------|--------|-------|-------|--------|--------|--------|--------|--------|-------|--------|---|-----|---|---|---|---|
| | A | B | C | D | AVG | A | B | A | B | C | D | AVG | A | B | A | B | C | D | AVG | A | B | C | D |
| ACETONITRILE | ND | ND | ND | ND | NA | 37000 | 19000 | 230 | 540 | 14193 | 110000 | 100000 | 100000 | 100000 | ND | ND | 106667 | | | | | | |
| ACRYLONITRILE | 64000 | 27000 | 26000 | 38000 | 38750 | 14000 | 14000 | 27000 | 21000 | 19000 | 48000 | 43000 | 43000 | 47000 | 26000 | 41000 | | | | | | | |
| BENZENE | 1800 | 5900 | 5100 | 8400 | 5300 | 2800 | 1400 | 2900 | 3400 | 2675 | 10000 | 13000 | 8600 | 10000 | 11000 | 10650 | | | | | | | |
| 2-BUTANONE (MEK) | 1500 | 13000 | 15000 | 30000 | 14875 | 2900 | 520 | 590 | 460 | 1118 | 14000 | 14000 | 14000 | 14000 | 22000 | 13800 | | | | | | | |
| CARBON TETRACHLORIDE | ND | ND | ND | ND | NA | ND | 2 | 6 | 31 | 13 | ND | ND | ND | ND | 24 | 24 | | | | | | | |
| CHLOROBENZENE | 940 | 1500 | 1100 | 2800 | 1585 | 350 | 110 | 480 | 1100 | 510 | 1400 | 1700 | 1500 | 1700 | 1600 | 1550 | | | | | | | |
| CHLOROFORM | ND | ND | ND | ND | NA | ND | ND | 15 | 80 | 48 | ND | ND | ND | ND | ND | 120 | | | | | | | |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | ND | NA | | | | | | | |
| TRANS-1,2-DICHLOROETHENE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | ND | NA | | | | | | | |
| ETHYLBENZENE | 610 | 4000 | 3700 | 8500 | 4203 | 810 | 130 | 180 | 100 | 305 | 2100 | 1400 | 2000 | 2000 | 3000 | 2125 | | | | | | | |
| METHYLENE CHLORIDE | 84 | ND | ND | ND | 84 | 21 | ND | 44 | 50 | 38 | 160 | 200 | 200 | 200 | ND | 160 | | | | | | | |
| PYRIDINE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | ND | NA | | | | | | | |
| TETRACHLOROETHENE | 710 | 1200 | 470 | 2100 | 1120 | 47 | 60 | 360 | 990 | 364 | 1600 | 1500 | 1900 | 1900 | 1700 | 1675 | | | | | | | |
| TOLUENE | 2300 | 4600 | 3500 | 1200 | 2900 | 1500 | 960 | 1400 | 1300 | 1290 | 6100 | 7400 | 6000 | 6000 | 5700 | 6300 | | | | | | | |
| 1,1,1-TRICHLOROETHANE | 26 | 12 | 26 | 50 | 29 | 11 | 5 | 11 | 27 | 14 | 100 | 140 | 140 | 140 | 68 | 117 | | | | | | | |
| TRICHLOROETHENE | 120 | 240 | 160 | 380 | 225 | 15 | 6 | 18 | 87 | 32 | 680 | 740 | 740 | 740 | 900 | 678 | | | | | | | |
| VINYL CHLORIDE | 5500 | 3500 | 3900 | 3900 | 4200 | 2000 | 740 | 1300 | 5300 | 2335 | 1400 | 3300 | 3300 | 3300 | 2200 | 2225 | | | | | | | |

TABLE 1 - RAW ANALYTICAL DATA FOR THE VOLATILE ORGANICS CAPTURED IN THE INLET SAMPLE TRAINS (CONTINUED)

VOLATILES DETECTED (ng) PER TRAP

| COMPOUND | RUN 04 | | | | RUN 05 | | | | RUN 06 | | | | | | |
|--------------------------|--------|------|-----|------|--------|-----|-----|------|--------|------|-----|-----|-----|-----|-----|
| | A | B | C | D | AVG | A | B | C | D | AVG | A | B | C | D | AVG |
| ACETONITRILE | ND | ND | 640 | 2100 | 1370 | ND | ND | 1900 | ND | 1900 | 690 | 240 | 850 | 130 | 478 |
| ACRYLONITRILE | 4700 | 2200 | ND | ND | 3450 | 590 | 580 | 2900 | 720 | 1198 | ND | ND | ND | ND | NA |
| BENZENE | 1300 | 1100 | 310 | 1200 | 978 | 350 | 550 | 200 | 750 | 463 | 690 | 370 | 490 | 170 | 430 |
| 2-BUTANONE (MEK) | 440 | 110 | 19 | 24 | 148 | 9 | 11 | 27 | 67 | 29 | 46 | 16 | 79 | ND | 47 |
| CARBON TETRACHLORIDE | 12 | 16 | 13 | 19 | 15 | ND | 2 | ND | ND | 2 | 2 | ND | 4 | ND | 3 |
| CHLOROBENZENE | 30 | 28 | ND | 64 | 41 | ND | ND | 22 | ND | 22 | ND | ND | ND | ND | NA |
| CHLOROFORM | 38 | 45 | 40 | 39 | 41 | ND | 6 | 5 | 4 | 5 | 11 | 8 | 22 | 9 | 13 |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA |
| TRANS-1,2-DICHLOROETHENE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA |
| ETHYLBENZENE | 390 | 120 | ND | 47 | 186 | 6 | 18 | 68 | 33 | 31 | 54 | 16 | 67 | ND | 46 |
| METHYLENE CHLORIDE | ND | ND | 18 | 19 | 19 | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA |
| PYRIDENE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA |
| TETRACHLOROETHENE | ND | 2 | ND | ND | 2 | 2 | 1 | ND | ND | 1 | 4 | ND | ND | ND | 4 |
| TOLUENE | 2100 | 850 | 34 | 710 | 924 | 28 | 130 | 410 | 250 | 205 | 390 | 110 | 460 | 39 | 250 |
| 1,1,1-TRICHLOROETHANE | ND | ND | 6 | 12 | 9 | 19 | 7 | 5 | 6 | 9 | 2 | ND | 5 | 2 | 3 |
| TRICHLOROETHENE | 2 | 1 | ND | 14 | 6 | 1 | ND | ND | 2 | 2 | 3 | ND | ND | ND | 3 |
| VINYL CHLORIDE | ND | ND | ND | 110 | NA | ND | ND | 36 | ND | NA | ND | ND | ND | ND | NA |

TABLE 1 - RAW ANALYTICAL DATA FOR THE VOLATILE ORGANICS CAPTURED IN THE INLET SAMPLE TRAINS (CONTINUED)

| COMPOUND | VOLATILES DETECTED (ng) PER TRAP | | | | | | | | | | | | AVERAGE | | | | AVERAGE | |
|--------------------------|----------------------------------|-----|-----|-----|--------|------|------|----|--------|-------|-------|-------|---------|-------|-------|------|---------|-------|
| | RUN 07 | | | | RUN 08 | | | | RUN 09 | | | | THRU | | THRU | | | |
| | A | B | C | D | A | B | C | D | A | B | C | D | AVG | D | AVG | D | AVG | D |
| ACETONITRILE | 6800 | 240 | ND | ND | 6800 | ND | ND | ND | 250 | 6200 | 14000 | 2600 | 6450 | 2600 | 60430 | 1249 | 4500 | 4500 |
| ACRYLONITRILE | 21000 | 450 | 210 | 150 | 5453 | 9600 | 2500 | ND | 6200 | 31000 | 54000 | 14000 | 30250 | 14000 | 32917 | 2324 | 13968 | 13968 |
| BENZENE | 1400 | 90 | 91 | 80 | 415 | 590 | 640 | ND | 517 | 2500 | 3100 | 870 | 2043 | 870 | 6208 | 623 | 991 | 991 |
| 2-BUTANONE (MEK) | ND | ND | ND | ND | NA | ND | ND | ND | NA | ND | ND | ND | NA | ND | 9931 | 75 | NA | NA |
| CARBON TETRACHLORIDE | 10 | 5 | 8 | 6 | 7 | ND | ND | ND | NA | 55 | 88 | 14 | 47 | 14 | 19 | 7 | 27 | 27 |
| CHLOROBENZENE | 56 | ND | ND | ND | 56 | 38 | 58 | ND | 48 | 120 | 240 | 30 | 109 | 30 | 1215 | 31 | 71 | 71 |
| CHLOROFORM | 12 | 4 | 4 | 6 | 7 | 24 | 32 | ND | 28 | 58 | 250 | 15 | 88 | 15 | 84 | 19 | 41 | 41 |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | NA | ND | ND | ND | NA | ND | ND | ND | NA | ND | NA | NA | NA | NA |
| TRANS-1,2-DICHLOROETHENE | ND | ND | ND | ND | NA | ND | ND | ND | NA | ND | ND | ND | NA | ND | NA | NA | NA | NA |
| ETHYLBENZENE | ND | ND | ND | ND | NA | ND | ND | ND | NA | 130 | ND | ND | NA | ND | 2211 | 88 | NA | NA |
| METHYLENE CHLORIDE | 1889 | 7 | 6 | 11 | 8 | 25 | 42 | ND | 40 | 3 | ND | ND | 3 | ND | 94 | NA | 17 | 17 |
| PYRIDINE | ND | ND | ND | ND | NA | ND | ND | ND | NA | ND | ND | ND | NA | ND | NA | NA | NA | NA |
| TETRACHLOROETHENE | 54 | 47 | 58 | 49 | 52 | 44 | 29 | ND | 84 | 31 | 120 | 22 | 51 | 22 | 1053 | 2 | 62 | 62 |
| TOLUENE | 54 | 5 | 6 | 10 | 19 | 11 | 18 | ND | 12 | 710 | 72 | 8 | 200 | 8 | 3497 | 459 | 77 | 77 |
| 1,1,1-TRICHLOROETHANE | 14 | 13 | 16 | 51 | 24 | 55 | 81 | ND | 75 | 37 | ND | ND | 37 | ND | 53 | 7 | 45 | 45 |
| TRICHLOROETHENE | 13 | 47 | 110 | 130 | 75 | 140 | 34 | ND | 70 | ND | 25 | 7 | 12 | 7 | 311 | 3 | 52 | 52 |
| VINYL CHLORIDE | 180 | ND | ND | ND | NA | ND | ND | ND | NA | 95 | 120 | 150 | 131 | 150 | 2920 | NA | NA | NA |

TABLE 2 - VOLATILE ORGANIC CONCENTRATION IN THE INLET FLUE GAS FOR SITE 4

FLUE GAS CONCENTRATION (ug/dscm)

| COMPOUND | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | AVERAGE | RUNS | AVERAGE | RUNS | AVERAGE | RUNS |
|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|-------|---------|-------|---------|-------|
| | 01-03 | 04-06 | 01-03 | 04-06 | 01-03 | 04-06 | 01-03 | 04-06 | 01-03 | 04-06 | 01-03 | 04-06 | 01-03 | 04-06 | 01-03 |
| ACETONITRILE | NA | 1434 | 11147 | 146 | 205 | 51.6 | 720 | 25.8 | 685 | 6290 | 134 | 477 | | | |
| ACRYLONITRILE | 4798 | 1985 | 4276 | 363 | 131 | NA | 577 | 640 | 3223 | 3686 | 247 | 1480 | | | |
| BENZENE | 621 | 278 | 1110 | 102 | 52.2 | 46.4 | 43.9 | 53.5 | 218 | 670 | 66.9 | 105 | | | |
| 2-BUTANONE (MEK) | 1709 | 113 | 1438 | 15.8 | 3.26 | 5.09 | NA | NA | NA | 1087 | 8.07 | NA | | | |
| CARBON TETRACHLORIDE | NA | 1.37 | 2.50 | 1.56 | 0.219 | 0.325 | 0.766 | NA | 5.01 | 1.94 | 0.701 | 2.89 | | | |
| CHLOROBENZENE | 187 | 53.4 | 162 | 4.26 | 2.37 | NA | 5.93 | 4.98 | 11.5 | 134 | 3.32 | 7.48 | | | |
| CHLOROFORM | NA | 5.02 | 12.5 | 4.21 | 0.557 | 1.36 | 0.686 | 2.91 | 9.27 | 8.77 | 2.04 | 4.29 | | | |
| 1,2-DICHLOROETHANE | NA | NA | NA | | | |
| TRANS-1,2-DICHLOROETHENE | NA | NA | NA | | | |
| ETHYLBENZENE | 485 | 30.9 | 222 | 19.8 | 3.47 | 4.93 | NA | NA | NA | 246 | 9.39 | NA | | | |
| METHYLENE CHLORIDE | 11.4 | 4.01 | 16.7 | 1.96 | NA | NA | 0.842 | 4.18 | 0.312 | 10.7 | NA | 1.78 | | | |
| PYRIDINE | NA | NA | NA | | | |
| TETRACHLOROETHENE | 133 | 38.4 | 175 | 0.189 | 0.157 | 0.426 | 5.49 | 8.72 | 5.38 | 115 | 0.257 | 6.53 | | | |
| TOLUENE | 352 | 134 | 657 | 97.7 | 22.8 | 27.0 | 1.98 | 1.21 | 20.9 | 381 | 49.2 | 8.02 | | | |
| 1,1,1-TRICHLOROETHANE | 3.38 | 1.41 | 12.2 | 0.957 | 1.02 | 0.326 | 2.46 | 7.80 | 3.85 | 5.66 | 0.767 | 4.71 | | | |
| TRICHLOROETHENE | 26.6 | 3.31 | 70.6 | 0.602 | 0.173 | 0.319 | 7.88 | 7.23 | 1.32 | 33.5 | 0.365 | 5.48 | | | |
| VINYL CHLORIDE | 513 | 244 | 232 | NA | NA | NA | NA | NA | 14.3 | 330 | NA | NA | | | |

TABLE 3 - VOLATILE ORGANIC MASS FLOW RATES AT THE INLET FOR SITE 4

| COMPOUND | MASS EMISSION RATES (mg/hr) | | | | | | | | | | | |
|--------------------------|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------------------|--------------------|--------------------|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | AVERAGE RUNS 01-03 | AVERAGE RUNS 04-06 | AVERAGE RUNS 07-09 |
| ACETONITRILE | ND | 11941 | 105705 | 972 | 1297 | 374 | 5249 | 202 | 5393 | 58823 | 881 | 3615 |
| ACRYLONITRILE | 35271 | 16530 | 40547 | 2419 | 831 | ND | 4209 | 5021 | 25370 | 30783 | 1625 | 11534 |
| BENZENE | 4562 | 2317 | 10527 | 680 | 330 | 336 | 320 | 420 | 1712 | 5802 | 449 | 817 |
| 2-BUTANONE (HEK) | 12565 | 945 | 13634 | 106 | 20.6 | 37 | ND | ND | ND | 9048 | 54.4 | NA |
| CARBON TETRACHLORIDE | ND | 11.4 | 23.7 | 10.4 | 1.39 | 2.35 | 5.58 | ND | 39.5 | 17.6 | 4.71 | 22.5 |
| CHLOROBENZENE | 1377 | 444 | 1533 | 28.4 | 15.0 | ND | 43.2 | 39.1 | 90.8 | 1118 | 21.7 | 57.7 |
| CHLOROFORM | ND | 41.8 | 119 | 28.1 | 3.53 | 9.82 | 5.00 | 22.8 | 73.0 | 80.3 | 13.8 | 33.6 |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| TRANS-1,2-DICHLOROETHENE | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| ETHYLBENZENE | 3567 | 258 | 2101 | 132 | 22 | 35.7 | ND | ND | ND | 1975 | 63.1 | NA |
| METHYLENE CHLORIDE | 84.0 | 33.4 | 158 | 13.1 | ND | ND | 6.14 | 32.8 | 2.46 | 91.9 | 13.1 | 13.8 |
| PYRIDENE | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| TETRACHLOROETHENE | 979 | 320 | 1656 | 1.26 | 0.994 | 3.08 | 40.0 | 68.3 | 42.3 | 985 | 1.78 | 50 |
| TOLUENE | 2584 | 1115 | 6229 | 652 | 144 | 195 | 14.4 | 9.49 | 164 | 3309 | 330 | 62.7 |
| 1,1,1-TRICHLOROETHANE | 24.8 | 11.7 | 116 | 6.38 | 6.44 | 2.36 | 18.0 | 61.2 | 30.3 | 50.7 | 5.06 | 36.5 |
| TRICHLOROETHENE | 196 | 27.5 | 670 | 4.02 | 1.09 | 2.31 | 57.4 | 56.7 | 10.4 | 298 | 2.47 | 41.5 |
| VINYL CHLORIDE | 3770 | 2028 | 2202 | ND | ND | ND | ND | ND | 112 | 2667 | NA | NA |

TABLE 4 - RAW ANALYTICAL DATA FOR THE VOLATILE ORGANICS CAPTURED IN THE OUTLET SAMPLE TRAINS

| COMPOUND | VOLATILES DETECTED (ng) PER TRAP | | | | | | | | | | | | | | |
|--------------------------|----------------------------------|-------|-------|-------|-------|--------|------|------|------|------|--------|-------|---------|-------|-------|
| | RUN 01 | | | | | RUN 02 | | | | | RUN 03 | | | | |
| | A | B | C | D | AVG | A | B | C | D | AVG | A | B | C | D | AVG |
| ACETONITRILE | ND | ND | ND | ND | NA | 3300 | 980 | 1400 | ND | 1893 | 16000 | 13000 | ND DATA | 5400 | 11467 |
| ACRYLONITRILE | 21000 | 36000 | 24000 | 25000 | 26500 | 3000 | 6200 | 4400 | 2700 | 4075 | 35000 | 38000 | ND DATA | 27000 | 33333 |
| BENZENE | 3900 | 5400 | 10000 | 7500 | 6700 | 2000 | 1100 | 1300 | 550 | 1238 | 6300 | 4400 | ND DATA | 4300 | 5000 |
| 2-BUTANONE (MEK) | 1200 | 25000 | 12000 | 2800 | 10250 | 180 | 20 | 39 | 30 | 67 | ND | ND | ND DATA | ND | NA |
| CARBON TETRACHLORIDE | 3 | ND | ND | ND | 3 | 19 | 6 | 10 | 4 | 10 | 14 | 15 | ND DATA | 18 | 16 |
| CHLOROBENZENE | 300 | 1700 | 970 | 280 | 813 | 500 | 20 | 42 | 18 | 145 | 880 | 440 | ND DATA | 530 | 617 |
| CHLOROFORM | 110 | 170 | ND | 240 | 173 | 330 | 270 | 320 | 180 | 275 | 310 | 300 | ND DATA | 350 | 320 |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND DATA | ND | NA |
| TRANS-1,2-DICHLOROETHENE | 5 | ND | ND | ND | 5 | ND | ND | ND | ND | NA | 7 | 6 | ND DATA | 5 | 6 |
| ETHYLBENZENE | 550 | 6900 | 2200 | 550 | 2550 | 770 | 22 | 70 | 26 | 222 | 640 | 30 | ND DATA | 90 | 253 |
| METHYLENE CHLORIDE | 892 | 1072 | 1872 | 2172 | 1502 | 1933 | 2333 | 2233 | 933 | 1858 | 1282 | 1182 | ND DATA | 842 | 1102 |
| PYRIDENE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND DATA | ND | NA |
| TETRACHLOROETHENE | 410 | 1400 | 1700 | 570 | 1020 | 740 | 320 | 940 | 610 | 653 | 1300 | 810 | ND DATA | 890 | 1000 |
| TOLUENE | 3600 | 8200 | 4900 | 5400 | 5525 | 2300 | 1200 | 2500 | 1900 | 1975 | 8800 | 2200 | ND DATA | 3400 | 4800 |
| 1,1,1-TRICHLOROETHANE | 290 | 510 | 950 | 810 | 640 | 1780 | 1480 | 2180 | 1080 | 1630 | 1069 | 1269 | ND DATA | 1069 | 1136 |
| TRICHLOROETHENE | 970 | 1800 | 2400 | 1900 | 1768 | 1700 | 1200 | 2200 | 1100 | 1550 | 1300 | 1200 | ND DATA | 1200 | 1233 |
| VINYL CHLORIDE | 1100 | 240 | 520 | 870 | 683 | 160 | 100 | 80 | 69 | 102 | 2700 | 2400 | ND DATA | 1700 | 2267 |

TABLE 4 - RAW ANALYTICAL DATA FOR THE VOLATILE ORGANICS CAPTURED IN THE OUTLET SAMPLE TRAINS (CONTINUED)

| COMPOUND | VOLATILES DETECTED (ng) PER TRAP | | | | | | | | | | | | | | | | | | AVERAGE | | AVERAGE | |
|--------------------------|----------------------------------|------|------|-----|------|-----|--------|-----|-----|-----|------|------|--------|------|------|-------|------|-------|---------|------|---------|--|
| | RUN 04 | | | | | | RUN 05 | | | | | | RUN 06 | | | | | | RUN 01 | | RUN 04 | |
| | A | B | C | D | AVG | D | A | B | C | D | AVG | D | A | B | C | D | AVG | THRU | RUN 03 | THRU | RUN 06 | |
| ACETONITRILE | 280 | 460 | 450 | 270 | 365 | 260 | 550 | ND | 290 | 367 | 1200 | 630 | 770 | 380 | 745 | 6680 | 492 | 6680 | 492 | | | |
| ACRYLONITRILE | 280 | 290 | ND | ND | 285 | 270 | 340 | 100 | 240 | 238 | 660 | 380 | 480 | 300 | 455 | 21303 | 326 | 21303 | 326 | | | |
| BENZENE | 480 | 160 | 130 | 21 | 198 | 55 | 97 | 22 | 72 | 62 | 89 | 70 | 88 | 75 | 81 | 4313 | 113 | 4313 | 113 | | | |
| 2-BUTANONE(MEK) | 32 | ND | 44 | ND | 38 | 12 | 29 | ND | 24 | 22 | 56 | 31 | 34 | ND | 40 | 5159 | 33 | 5159 | 33 | | | |
| CARBON TETRACHLORIDE | 10 | 12 | 9 | ND | 11 | 6 | 3 | 2 | 4 | 4 | ND | 6 | ND | ND | 6 | 9 | 7 | 9 | 7 | | | |
| CHLOROBENZENE | ND | ND | ND | ND | NA | 5 | 10 | ND | 4 | 6 | 19 | ND | ND | ND | NA | 525 | NA | 525 | NA | | | |
| CHLOROFORM | 380 | 410 | 360 | 230 | 345 | 260 | 360 | 180 | 290 | 273 | 430 | 320 | 440 | 300 | 373 | 256 | 330 | 256 | 330 | | | |
| 1,2-DICHLOROETHANE | 45 | 35 | 36 | 12 | 32 | 9 | 19 | 4 | 13 | 11 | 24 | 15 | 23 | 13 | 19 | NA | 21 | NA | 21 | | | |
| TRANS-1,2-DICHLOROETHENE | ND | ND | ND | ND | NA | 1 | 2 | 1 | 1 | 1 | ND | ND | ND | ND | NA | NA | NA | NA | NA | | | |
| ETHYLBENZENE | 13 | 24 | 96 | ND | 19 | 5 | 6 | ND | 2 | 4 | 23 | 11 | 14 | ND | 16 | 1008 | 13 | 1008 | 13 | | | |
| METHYLENE CHLORIDE | 425 | 545 | 425 | 415 | 453 | 117 | 157 | 127 | 117 | 130 | 330 | 230 | 310 | 210 | 270 | 1487 | 284 | 1487 | 284 | | | |
| PYRIDENE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | NA | NA | NA | NA | | | |
| TETRACHLOROETHENE | 620 | 520 | 710 | 190 | 510 | 430 | 650 | 180 | 400 | 415 | 1300 | 690 | 1100 | 530 | 905 | 891 | 610 | 891 | 610 | | | |
| TOLUENE | 620 | 510 | 700 | 160 | 498 | 110 | 370 | 79 | 240 | 200 | 890 | 480 | 770 | 370 | 628 | 4100 | 442 | 4100 | 442 | | | |
| 1,1,1-TRICHLOROETHANE | 910 | 1000 | 860 | 360 | 783 | 685 | 995 | 335 | 915 | 733 | 1500 | 1000 | 1500 | 1000 | 1250 | 1135 | 922 | 1135 | 922 | | | |
| TRICHLOROETHENE | 1200 | 1200 | 1200 | 530 | 1033 | 950 | 1500 | 490 | 27 | 742 | 1600 | 1100 | 1500 | 970 | 1293 | 1517 | 1022 | 1517 | 1022 | | | |
| VINYL CHLORIDE | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | ND | ND | ND | ND | NA | 1017 | NA | 1017 | NA | | | |

TABLE 5 - VOLATILE ORGANIC CONCENTRATION IN THE OUTLET FLUE GAS FOR SITE 4

| FLUE GAS CONCENTRATION (ug/dscm) | | | | | | | | |
|----------------------------------|--------|--------|--------|--------|--------|--------|-----------------------|-----------------------|
| COMPOUND | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | AVERAGE RUNS 01-03 | AVERAGE RUNS 04-06 |
| ACETONITRILE | NA | 189 | 1145 | 36.4 | 36.6 | 74.3 | 667 | 49.1 |
| ACRYLONITRILE | 2642 | 407 | 3325 | 28.4 | 23.7 | 45.4 | 2124 | 32.5 |
| BENZENE | 667 | 123 | 498 | 19.7 | 6.13 | 8.02 | 430 | 11.3 |
| 2-BUTANONE (MEK) | 1025 | 6.70 | NA | 3.79 | 2.16 | 4.03 | 516 | 3.33 |
| CARBON TETRACHLORIDE | 0.299 | 0.97 | 1.56 | 1.10 | 0.374 | 0.301 | 0.944 | 0.591 |
| CHLOROBENZENE | 81.2 | 14.5 | 61.5 | NA | 0.63 | 33.5 | 52.4 | 17.0 |
| CHLOROFORM | 17.3 | 27.4 | 31.9 | 34.4 | 27.2 | 37.1 | 25.5 | 32.9 |
| 1,2-DICHLOROETHANE | NA | NA | NA | 3.19 | 1.12 | 1.87 | NA | 2.06 |
| TRANS-1,2-DICHLOROETHENE | 5.00 | NA | 0.598 | NA | 0.125 | NA | 2.80 | NA |
| ETHYLBENZENE | 255 | 22.1 | 25.3 | 1.85 | 0.433 | 1.60 | 101 | 1.29 |
| METHYLENE CHLORIDE | 149 | 185 | 110 | 45.1 | 12.9 | 26.9 | 148 | 28.3 |
| PYRIDINE | NA | NA |
| TETRACHLOROETHENE | 102 | 65.0 | 100 | 50.8 | 41.4 | 90.2 | 88.8 | 60.8 |
| TOLUENE | 551 | 197 | 478 | 49.6 | 19.9 | 62.5 | 409 | 44.0 |
| 1,1,1-TRICHLOROETHANE | 63.7 | 162 | 113 | 78.0 | 73.0 | 125 | 113 | 91.8 |
| TRICHLOROETHENE | 176 | 154 | 123 | 103 | 74.2 | 129 | 151 | 102 |
| VINYL CHLORIDE | 67.9 | 10.2 | 226 | NA | NA | NA | 101 | NA |

TABLE 6 - VOLATILE ORGANIC MASS EMISSION RATES AT THE OUTLET FOR SITE 4

| MASS EMISSION RATES (ug/hr) | | | | | | | | |
|-----------------------------|--------|--------|--------|--------|--------|--------|-----------------------|-----------------------|
| COMPOUND | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | AVERAGE RUNS 01-03 | AVERAGE RUNS 04-06 |
| ACETONITRILE | ND | 1764 | 11235 | 330 | 346 | 769 | 6499 | 482 |
| ACRYLONITRILE | 28326 | 3795 | 32626 | 258 | 224 | 469 | 21582 | 317 |
| BENZENE | 7151 | 1152 | 4891 | 179 | 58.0 | 83.0 | 4398 | 107 |
| 2-BUTANONE (MEK) | 10987 | 62.6 | ND | 34.4 | 20.4 | 41.7 | 5525 | 32.2 |
| CARBON TETRACHLORIDE | 3.21 | 9.08 | 15.3 | 10.0 | 3.53 | 3.11 | 9.20 | 5.54 |
| CHLOROBENZENE | 870 | 135 | 603 | ND | 5.98 | 346 | 536 | 176 |
| CHLOROFORM | 185 | 256 | 313 | 312 | 257 | 384 | 251 | 318 |
| 1,2-DICHLOROETHANE | ND | ND | ND | 29.0 | 10.61 | 19.3 | NA | 19.6 |
| TRANS-1,2-DICHLOROETHENE | 53.6 | ND | 5.87 | ND | 1.180 | ND | 29.7 | NA |
| ETHYLBENZENE | 2735 | 207 | 248 | 16.8 | 4.10 | 16.5 | 1063 | 12.5 |
| METHYLENE CHLORIDE | 1602 | 1730 | 1079 | 409 | 122 | 278 | 1470 | 270 |
| PYRIDINE | ND | ND | ND | ND | ND | ND | NA | NA |
| TETRACHLOROETHENE | 1091 | 606 | 978 | 462 | 392 | 933 | 892 | 596 |
| TOLUENE | 5906 | 1836 | 4694 | 451 | 188 | 647 | 4145 | 429 |
| 1,1,1-TRICHLOROETHANE | 683 | 1517 | 1111 | 708 | 691 | 1289 | 1104 | 896 |
| TRICHLOROETHENE | 1887 | 1442 | 1206 | 935 | 702 | 1333 | 1512 | 990 |
| VINYL CHLORIDE | 728 | 95.2 | 2219 | ND | ND | ND | 1014 | NA |

TABLE 7 - VOLATILE ORGANIC CONCENTRATION IN THE SLUDGE FEED FOR SITE 4

| COMPOUND | CONCENTRATION (ug/kg) | | | | | | | | | | |
|--------------------------|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|---------|--|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | AVERAGE | |
| ACETONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| ACRYLONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| BENZENE | 6 | 3 | 5 | 3 | ND | 4 | N/A | N/A | ND | 4 | |
| 2-BUTANONE (MEK) | 570 | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| CARBON TETRACHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| CHLOROBENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| CHLOROFORM | 21 | 23 | 21 | 7 | 20 | 28 | N/A | N/A | ND | 20 | |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| TRANS-1,2-DICHLOROETHENE | ND | 20 | 20 | 8 | 25 | 36 | N/A | N/A | ND | 22 | |
| ETHYLBENZENE | 6 | 12 | 13 | 5 | 10 | 16 | N/A | N/A | ND | 10 | |
| METHYLENE CHLORIDE | 24 | 38 | 110 | 45 | 17 | 44 | N/A | N/A | 91 | 53 | |
| PYRIDINE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |
| TETRACHLOROETHENE | 330 | 270 | 330 | 71 | 100 | 170 | N/A | N/A | 130 | 200 | |
| TOLUENE | ND | 300 | 320 | 100 | 25 | 400 | N/A | N/A | 910 | 294 | |
| 1,1,1-TRICHLOROETHANE | ND | 51 | 67 | 16 | 38 | 55 | N/A | N/A | 59 | 41 | |
| TRICHLOROETHENE | ND | 240 | 260 | 52 | 87 | 120 | N/A | N/A | 26 | 112 | |
| VINYL CHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | |

TABLE B - VOLATILE ORGANIC FEED RATE IN THE SLUDGE FEED FOR SITE 4

| COMPOUND | FEED RATE (mg/hr) | | | | | | | | | | | | | AVERAGE |
|--------------------------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|-----|-----|----|-----|---------|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | | | | | |
| ACETONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| ACRYLONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| BENZENE | 12 | 5.6 | 10 | 5.5 | ND | 8.2 | N/A | N/A | ND | ND | 8.3 | NA | 8.3 | |
| 2-BUTANONE (MEK) | 1148 | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| CARBON TETRACHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| CHLOROBENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| CHLOROFORM | 42 | 43 | 42 | 13 | 41 | 57 | N/A | N/A | ND | ND | 40 | NA | 40 | |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| TRANS-1,2-DICHLOROETHENE | ND | 38 | 40 | 15 | 51 | 74 | N/A | N/A | ND | ND | 44 | NA | 44 | |
| ETHYLBENZENE | 12 | 23 | 26 | 9 | 20 | 33 | N/A | N/A | ND | ND | 21 | NA | 21 | |
| METHYLENE CHLORIDE | 48 | 71 | 223 | 83 | 35 | 90 | N/A | N/A | 177 | 104 | NA | NA | 104 | |
| PYRIDINE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |
| TETRACHLOROETHENE | 665 | 507 | 668 | 130 | 204 | 349 | N/A | N/A | 254 | 396 | NA | NA | 396 | |
| TOLUENE | ND | 563 | 647 | 184 | 51 | 820 | N/A | N/A | 1775 | 673 | NA | NA | 673 | |
| 1,1,1-TRICHLOROETHANE | ND | 96 | 136 | 29 | 78 | 113 | N/A | N/A | 115 | 94 | NA | NA | 94 | |
| TRICHLOROETHENE | ND | 451 | 526 | 96 | 178 | 246 | N/A | N/A | 51 | 258 | NA | NA | 258 | |
| VINYL CHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | ND | NA | NA | NA | |

TABLE 9 - VOLATILE ORGANIC CONCENTRATION IN THE SCRUBBER WATER INFLUENT FOR SITE 4

CONCENTRATION (ug/l)

| COMPOUND | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | AVERAGE |
|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| ACETONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| ACRYLONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| BENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| 2-BUTANONE (HEX) | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| CARBON TETRACHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| CHLOROBENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| CHLOROFORM | 3 | 3 | 3 | 2 | 4 | 4 | N/A | N/A | 3 | 3 |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| TRANS-1,2-DICHLOROETHENE | 3 | 2 | 2 | 2 | 2 | 4 | N/A | N/A | 3 | 3 |
| ETHYLBENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| METHYLENE CHLORIDE | 29 | 41 | 30 | 23 | 15 | 5 | N/A | N/A | 24 | 24 |
| PYRIDINE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |
| TETRACHLOROETHENE | 11 | 6 | 7 | 6 | 59 | 9 | N/A | N/A | 33 | 19 |
| TOLUENE | ND | ND | ND | ND | ND | 2 | N/A | N/A | ND | NA |
| 1,1,1-TRICHLOROETHANE | 18 | 8 | 17 | 12 | 11 | 19 | N/A | N/A | 14 | 14 |
| TRICHLOROETHENE | 40 | 14 | 16 | 11 | 12 | 15 | N/A | N/A | 18 | 18 |
| VINYL CHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA |

TABLE 10 - VOLATILE ORGANIC FEED RATE IN THE SCRUBBER WATER INFLEUENT FOR SITE 4

| COMPOUND | FEED RATE (mg/hr) | | | | | | | | | | | | |
|--------------------------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|---------|--|--|--|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | AVERAGE | | | |
| ACETONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| ACRYLONITRILE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| BENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| 2-BUTANONE (HEX) | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| CARBON TETRACHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| CHLOROBENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| CHLOROFORM | 134 | 134 | 134 | 89 | 178 | 178 | N/A | N/A | 134 | 146 | | | |
| 1,2-DICHLOROETHANE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| TRANS-1,2-DICHLOROETHENE | 134 | 89 | 89 | 89 | 89 | 178 | N/A | N/A | 134 | 114 | | | |
| ETHYLBENZENE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| METHYLENE CHLORIDE | 1291 | 1825 | 1335 | 1024 | 668 | 223 | N/A | N/A | 1068 | 1062 | | | |
| PYRIDINE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |
| TETRACHLOROETHENE | 490 | 267 | 312 | 267 | 2626 | 401 | N/A | N/A | 1469 | 833 | | | |
| TOLUENE | ND | ND | ND | ND | ND | 89 | N/A | N/A | ND | NA | | | |
| 1,1,1-TRICHLOROETHANE | 801 | 356 | 757 | 534 | 490 | 846 | N/A | N/A | 623 | 630 | | | |
| TRICHLOROETHENE | 1780 | 623 | 712 | 490 | 534 | 668 | N/A | N/A | 801 | 801 | | | |
| VINYL CHLORIDE | ND | ND | ND | ND | ND | ND | N/A | N/A | ND | NA | | | |

A.2 PRELIMINARY HEXAVALENT CHROMIUM, DIOXIN/FURAN, SEMI-VOLATILES,
AND METALS RESULTS; DECEMBER 22, 1987

December 22, 1987

Dr. Harry Bostian
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
26 W. St. Clair Street
Cincinnati, Ohio 45268

Dear Harry:

Enclosed are additional preliminary results for the fourth Sewage Sludge Test at Cranston, R.I. Included in this letter are the hexavalent chromium results, dioxin/furan results, semi-volatile organic results, and the metals results for the sludge feed, scrubber water influent, scrubber water effluent, and bottom ash samples. Since three different operating modes were used during this test, Table 1 is included to specify the operating conditions for each run which is included in this preliminary data letter. The preliminary results are presented as follows:

Attachment A: Hexavalent Chromium Results

Attachment B: Dioxin/Furan Results
No sludge feed results are available at this time. These samples are being reanalyzed by Triangle Laboratories. They will be available on January 13, 1988.

Attachment C: Semi-volatile Results

Attachment D: Metals Results
The metals results for the flue gas samples are not available at this time. They will be forwarded to you as soon as we receive them from the Sacramento Laboratory. The metals results for the sludge feed, scrubber water influent, scrubber water effluent and bottom ash samples are included.

If you have any questions concerning these results or need any additional information, please contact Keith Barnett at (919) 541-9100 or me at (919) 481-0212.

Sincerely,



Dennis R. Knisley
Chemical Engineer

Attachments A,B,C and D

cc: Gene Crumpler, U.S. EPA
Robert M. Dykes,
Keith Barnett, Radian
Mike Palazzolo, Radian
Mike Lewis, Technical Consultant

TABLE 1. SUMMARY OF THE INCINERATOR OPERATING CONDITIONS FOR THE FOURTH SEWAGE SLUDGE TEST^a

| | | |
|-----------------------|----------------------|-------------------------------|
| Cr ⁺⁶ - 01 | Outlet Stack | Hot Furnace, Afterburner On |
| Cr ⁺⁶ - 02 | | Cool Furnace, Afterburner Off |
| Cr ⁺⁶ - 03 | | Cool Furnace, Afterburner Off |
| Cr ⁺⁶ - 04 | | Cool Furnace, Afterburner Off |
| Dioxin/Furan - 01 | Outlet Stack | Cool Furnace, Afterburner Off |
| Dioxin/Furan - 02 | | Cool Furnace, Afterburner Off |
| Dioxin/Furan - 03 | | Cool Furnace, Afterburner Off |
| Dioxin/Furan - 04 | | Hot Furnace, Afterburner Off |
| Dioxin/Furan - 05 | | Hot Furnace, Afterburner Off |
| Dioxin/Furan - 06 | | Hot Furnace, Afterburner Off |
| Semi-Volatile - 01 | Control Device Inlet | Cool Furnace, Afterburner Off |
| Semi-Volatile - 02 | | Hot Furnace, Afterburner Off |
| Semi-Volatile - 03 | | Cool Furnace, Afterburner Off |
| M12 - 02 | Control Device Inlet | Cool Furnace, Afterburner Off |
| M12 - 04 ^b | | Hot Furnace, Afterburner On |
| M12 - 06 ^b | | Cool Furnace, Afterburner Off |
| M12 - 07 ^b | | Cool Furnace, Afterburner Off |
| M12 - 08 ^b | | Cool Furnace, Afterburner Off |
| M12 - 01 | Outlet Stack | Cool Furnace, Afterburner Off |
| M12 - 02 | | Cool Furnace, Afterburner Off |
| M12 - 03 | | Cool Furnace, Afterburner Off |
| M12 - 04 | | Hot Furnace, Afterburner On |
| M12 - 05 | | Cool Furnace, Afterburner Off |
| M12 - 06 | | Hot Furnace, Afterburner Off |
| M12 - 07 ^b | | Hot Furnace, Afterburner Off |
| M12 - 08 ^b | | Cool Furnace, Afterburner Off |
| M12 - 09 ^b | | Cool Furnace, Afterburner Off |
| M12 - 10 ^b | | Cool Furnace, Afterburner Off |
| M12 - 11 | | Hot Furnace, Afterburner Off |

^aThe "Cool Furnace" operating condition is characterized by a combustion hearth temperature approximately 400°F less than when the incinerator is operating under the "Hot Furnace" conditions. The higher temperatures are maintained under the "Hot Furnace" operating conditions by burning auxiliary fuel.

^bThese runs were conducted concurrently at the control device inlet and outlet.



ATTACHMENT A

HEXAVALENT CHROMIUM RESULTS

TABLE A-1. RESULTS OF THE HEXAVALENT CHROMIUM ANALYSES
FOR THE FLUE GAS SAMPLES

| Run Number | Chromium III | | Chromium VI | |
|-------------------|----------------------|----------------------------------|-----------------------------|------------------------------------|
| | Amount Detected (ug) | Flue Gas Concentration (ug/dscm) | Sample Detection Limit (ug) | Flue Gas Detection Limit (ug/dscm) |
| <u>Front Half</u> | | | | |
| 01 | 5.6 | 1.6 | < 100 | < 28.3 |
| 02 | 5.3 | 1.0 | < 100 | < 18.9 |
| 03 | 5.6 | 1.3 | < 100 | < 22.3 |
| 04 | 5.7 | 0.94 | < 100 | < 18.7 |
| <u>Back Half</u> | | | | |
| 01 | 5.8 | 1.6 | < 100 | < 28.3 |
| 02 | 3.2 | 0.61 | < 100 | < 18.9 |
| 03 | 3.6 | 0.80 | < 100 | < 22.3 |
| 04 | 3.8 | 0.71 | < 100 | < 18.7 |

TABLE A-2. RESULTS OF THE HEXAVALENT CHROMIUM ANALYSES
FOR THE SLUDGE FEED SAMPLES

| Run Number | Chromium III | Chromium IV |
|---------------|------------------------------|--|
| | Amount Detected (ug/g) | Sample Detection Limit (ug/g) |
| 01 | 166 | <13.2 |
| 02 | 174 | <13.8 |
| 03 | 205 | <15.1 |
| 04 | 157 | <12.7 |

ATTACHMENT B
DIOXIN/FURAN RESULTS

TABLE B-1. MODIFIED METHOD 5 TRAIN DIOXIN/FURAN RESULTS

| ===== | | | | | | | |
|----------------------|---------|---------|-----------|---------|---------|---------|---------|
| AMOUNT DETECTED (ng) | | | | | | | |
| ISOMER | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | AVERAGE |
| ===== | | | | | | | |
| DIOXIN | | | | | | | |
| Mono-CDD | [1.144] | [0.470] | [1.501] | [0.003] | [0.003] | [0.955] | 0.00 |
| Di-CDD | 51.72 | 1.25 | [101.602] | 30.16 | 2.79 | 1.64 | 14.59 |
| Tri-CDD | 55.59 | 66.11 | 39.70 | 5.94 | 43.25 | 43.27 | 42.31 |
| 2378 TCDD | 0.61 | 0.65 | 0.65 | 0.07 | [0.003] | 0.40 | 0.40 |
| Other TCDD | 42.91 | 36.41 | 28.25 | 8.00 | 52.48 | 54.02 | 37.01 |
| 12378 PCDD | 0.60 | 0.89 | 0.65 | 0.15 | 0.97 | 0.96 | 0.70 |
| Other PCDD | 14.40 | 14.42 | 9.48 | 3.86 | 27.85 | 28.88 | 16.48 |
| 123478 HxCDD | 0.31 | 0.38 | 0.31 | 0.11 | 0.69 | 0.64 | 0.40 |
| 123678 HxCDD | 0.62 | 0.70 | 0.58 | 0.22 | 1.42 | 1.41 | 0.82 |
| 123789 HxCDD | [0.780] | 1.32 | 1.04 | 0.37 | 2.04 | 1.97 | 1.12 |
| Other HxCDD | 9.33 | 8.34 | 7.55 | 3.32 | 19.17 | 18.31 | 11.00 |
| 1234678 HpCDD | 2.36 | 2.59 | 2.60 | 1.01 | 4.04 | 3.74 | 2.72 |
| Other HpCDD | 2.55 | 2.80 | 2.66 | 1.12 | 5.23 | 4.16 | 3.09 |
| Octa-CDD | 6.187 | 6.92 | 6.31 | 1.33 | 5.33 | 3.37 | 4.91 |
| TOTAL CDD | 187.19 | 142.77 | 99.77 | 55.66 | 165.25 | 162.76 | 135.56 |
| FURAN | | | | | | | |
| Mono-CDF | 12.81 | 8.76 | 9.31 | 1.26 | 23.14 | 10.73 | 11.00 |
| Di-CDF | 6.25 | 138.65 | 65.39 | 8.99 | 149.79 | 75.12 | 74.03 |
| Tri-CDF | 121.97 | 367.69 | 176.84 | 62.95 | 233.26 | 214.39 | 196.18 |
| 2378 TCDF | 20.91 | 20.09 | 23.38 | 5.70 | 20.51 | 18.29 | 18.15 |
| Other TCDF | 113.95 | 155.41 | 145.55 | 28.77 | 110.70 | 106.07 | 110.07 |
| 12378 PCDF | 1.53 | 3.46 | 1.28 | 0.48 | 1.54 | 1.48 | 1.63 |
| 23478 PCDF | 4.05 | 5.92 | 6.49 | 1.10 | 5.19 | 5.13 | 4.65 |
| Other PCDF | 32.68 | 49.62 | 38.53 | 11.14 | 38.41 | 43.17 | 35.59 |
| 123478 HxCDF | 3.16 | 4.17 | 4.87 | 1.34 | 6.94 | 6.30 | 4.46 |
| 123678 HxCDF | 1.23 | 1.78 | 1.65 | 0.51 | 2.32 | 2.17 | 1.61 |
| 234678 HxCDF | 1.82 | 2.70 | 1.93 | 0.99 | 4.01 | 4.12 | 2.59 |
| 123789 HxCDF | [.140] | 0.21 | 0.16 | 0.06 | 0.23 | 0.21 | 0.14 |
| Other HxCDF | 8.83 | 13.00 | 13.44 | 3.42 | 17.26 | 14.55 | 11.75 |
| 1234678 HpCDF | 3.52 | 4.69 | 4.33 | 2.06 | 12.44 | 10.53 | 6.26 |
| 1234789 HpCDF | [0.414] | [0.687] | 0.49 | 0.25 | 1.10 | 1.00 | 0.47 |
| Other HpCDF | 2.17 | 3.06 | 2.26 | 1.46 | 5.96 | 4.98 | 3.31 |
| Octa-CDF | 1.38 | 2.27 | 1.32 | 0.96 | 2.92 | 2.50 | 1.89 |
| TOTAL PCDF | 336.26 | 781.46 | 497.20 | 131.43 | 635.70 | 520.71 | 483.79 |
| TOTAL CDD/CDF | 523.44 | 924.22 | 596.96 | 187.09 | 800.95 | 683.47 | 619.36 |
| ===== | | | | | | | |

TABLE B-2. DIONIN/FURAN FLUE GAS CONCENTRATIONS AT THE OUTLET

| ===== | | | | | | | |
|-------------------------|--------|--------|--------|--------|--------|--------|---------|
| CONCENTRATION (ng/dscm) | | | | | | | |
| ISOMER | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | AVERAGE |
| ===== | | | | | | | |
| DIOXIN | | | | | | | |
| Mono-CDD | ND | ND | ND | ND | ND | ND | NA |
| Di-CDD | 10.24 | 0.27 | ND | 6.53 | 0.57 | 0.33 | 7.73 |
| Tri-CDD | 11.00 | 14.53 | 7.59 | 1.29 | 8.87 | 8.68 | 8.66 |
| 2378 TCDD | 0.12 | 0.14 | 0.12 | 0.02 | ND | 0.08 | 0.18 |
| Other TCDD | 8.49 | 8.00 | 5.40 | 1.73 | 10.76 | 10.83 | 7.54 |
| 12378 PCDD | 0.12 | 0.20 | 0.12 | 0.03 | 0.20 | 0.19 | 0.14 |
| Other PCDD | 2.85 | 3.17 | 1.81 | 0.84 | 5.71 | 5.79 | 3.36 |
| 123478 HxCDD | 0.06 | 0.08 | 0.06 | 0.02 | 0.14 | 0.13 | 0.08 |
| 123678 HxCDD | 0.12 | 0.15 | 0.11 | 0.05 | 0.29 | 0.28 | 0.17 |
| 123789 HxCDD | ND | 0.29 | 0.20 | 0.08 | 0.42 | 0.40 | 0.28 |
| Other HxCDD | 1.85 | 1.83 | 1.44 | 0.72 | 3.93 | 3.67 | 2.24 |
| 1234678 HpCDD | 0.47 | 0.57 | 0.50 | 0.22 | 0.83 | 0.75 | 0.56 |
| Other HpCDD | 0.51 | 0.62 | 0.51 | 0.24 | 1.07 | 0.83 | 0.63 |
| Octa-CDD | 1.22 | 1.52 | 1.21 | 0.29 | 1.09 | 0.68 | 1.00 |
| TOTAL CDD | 37.05 | 31.38 | 19.06 | 12.05 | 33.88 | 32.64 | 27.68 |
| FURAN | | | | | | | |
| Mono-CDF | 2.54 | 1.93 | 1.78 | 0.27 | 4.74 | 2.15 | 2.24 |
| Di-CDF | 1.24 | 30.48 | 12.49 | 1.95 | 30.71 | 15.07 | 15.32 |
| Tri-CDF | 24.14 | 80.82 | 33.79 | 13.63 | 47.82 | 43.00 | 40.54 |
| 2378 TCDF | 4.14 | 4.42 | 4.47 | 1.23 | 4.20 | 3.67 | 3.69 |
| Other TCDF | 22.56 | 34.16 | 27.81 | 6.23 | 22.70 | 21.27 | 22.45 |
| 12378 PCDF | 0.30 | 0.76 | 0.25 | 0.10 | 0.32 | 0.30 | 0.34 |
| 23478 PCDF | 0.80 | 1.30 | 1.24 | 0.24 | 1.06 | 1.03 | 0.95 |
| Other PCDF | 6.47 | 10.91 | 7.36 | 2.41 | 7.87 | 8.66 | 7.28 |
| 123478 HxCDF | 0.63 | 0.92 | 0.93 | 0.29 | 1.42 | 1.26 | 0.91 |
| 123678 HxCDF | 0.24 | 0.39 | 0.32 | 0.11 | 0.48 | 0.44 | 0.33 |
| 234678 HxCDF | 0.36 | 0.59 | 0.37 | 0.21 | 0.82 | 0.83 | 0.53 |
| 123789 HxCDF | ND | 0.05 | 0.03 | 0.01 | 0.05 | 0.04 | 0.04 |
| Other HxCDF | 1.75 | 2.86 | 2.57 | 0.74 | 3.54 | 2.92 | 2.40 |
| 1234678 HpCDF | 0.70 | 1.03 | 0.83 | 0.45 | 2.55 | 2.11 | 1.28 |
| 1234789 HpCDF | ND | ND | 0.09 | 0.05 | 0.23 | 0.20 | 0.14 |
| Other HpCDF | 0.43 | 0.67 | 0.43 | 0.32 | 1.22 | 1.00 | 0.68 |
| Octa-CDF | 0.27 | 0.50 | 0.25 | 0.21 | 0.60 | 0.50 | 0.39 |
| TOTAL CDF | 66.56 | 171.78 | 95.01 | 28.46 | 130.33 | 104.44 | 99.43 |
| TOTAL CDD/CDF | 103.61 | 203.16 | 114.07 | 40.51 | 164.21 | 137.08 | 127.11 |
| ===== | | | | | | | |

TABLE B-3. DIOXIN/FURAN MASS EMISSION RATES

| MASS EMISSION RATE (ug/hr) | | | | | | | |
|----------------------------|----------------|----------------|----------------|---------------|----------------|----------------|----------------|
| ISGMR | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | AVERAGE |
| DIOXIN | | | | | | | |
| Mono-CDD | ND | ND | ND | ND | ND | ND | NA |
| Di-CDD | 115.25 | 2.91 | ND | 66.00 | 6.02 | 3.67 | 84.31 |
| Tri-CDD | 123.88 | 153.88 | 90.04 | 12.99 | 93.39 | 96.81 | 95.17 |
| 2378 TCDD | 1.36 | 1.50 | 1.48 | 0.16 | ND | 0.90 | 2.03 |
| Other TCDD | 95.62 | 84.74 | 64.07 | 17.50 | 113.33 | 120.86 | 82.69 |
| 12378 PCDD | 1.35 | 2.07 | 1.48 | 0.33 | 2.09 | 2.16 | 1.58 |
| Other PCDD | 32.08 | 33.55 | 21.49 | 8.44 | 60.14 | 64.62 | 36.72 |
| 123478 HxCDD | 0.69 | 0.88 | 0.69 | 0.25 | 1.48 | 1.43 | 0.90 |
| 123678 HxCDD | 1.37 | 1.62 | 1.31 | 0.49 | 3.07 | 3.15 | 1.83 |
| 123789 HxCDD | ND | 3.07 | 2.35 | 0.81 | 4.40 | 4.41 | 3.01 |
| Other HxCDD | 20.80 | 19.41 | 17.12 | 7.27 | 41.40 | 40.97 | 24.49 |
| 1234678 HpCDD | 5.26 | 6.03 | 5.90 | 2.21 | 8.73 | 8.36 | 6.08 |
| Other HpCDD | 5.69 | 6.52 | 6.04 | 2.45 | 11.28 | 9.30 | 6.88 |
| Octa-CDD | 13.79 | 16.12 | 14.30 | 2.90 | 11.51 | 7.54 | 11.03 |
| TOTAL CDD | 417.14 | 332.30 | 226.28 | 121.80 | 356.84 | 364.17 | 303.09 |
| FURAN | | | | | | | |
| Mono-CDF | 28.54 | 20.39 | 21.12 | 2.76 | 49.97 | 24.01 | 24.47 |
| Di-CDF | 13.93 | 322.73 | 148.31 | 19.67 | 323.46 | 168.07 | 166.03 |
| Tri-CDF | 271.80 | 855.83 | 401.10 | 137.76 | 503.72 | 479.69 | 441.65 |
| 2378 TCDF | 46.59 | 46.75 | 53.04 | 12.48 | 44.29 | 40.93 | 40.68 |
| Other TCDF | 253.92 | 361.73 | 330.12 | 62.95 | 239.05 | 237.33 | 247.52 |
| 12378 PCDF | 3.42 | 8.05 | 2.91 | 1.06 | 3.33 | 3.30 | 3.68 |
| 23478 PCDF | 9.03 | 13.77 | 14.71 | 2.41 | 11.20 | 11.47 | 10.43 |
| Other PCDF | 72.81 | 115.50 | 87.40 | 24.38 | 82.94 | 96.59 | 79.94 |
| 123478 HxCDF | 7.04 | 9.70 | 11.04 | 2.94 | 14.98 | 14.09 | 9.97 |
| 123678 HxCDF | 2.73 | 4.14 | 3.74 | 1.11 | 5.01 | 4.86 | 3.60 |
| 234678 HxCDF | 4.05 | 6.28 | 4.38 | 2.16 | 8.66 | 9.21 | 5.79 |
| 123789 HxCDF | ND | 0.49 | 0.36 | 0.12 | 0.49 | 0.47 | 0.39 |
| Other HxCDF | 19.67 | 30.26 | 30.47 | 7.49 | 37.27 | 32.55 | 26.29 |
| 1234678 HpCDF | 7.85 | 10.90 | 9.81 | 4.50 | 26.85 | 23.55 | 13.91 |
| 1234789 HpCDF | ND | ND | 1.10 | 0.54 | 2.38 | 2.23 | 1.56 |
| Other HpCDF | 4.84 | 7.13 | 5.12 | 3.19 | 12.86 | 11.13 | 7.38 |
| Octa-CDF | 3.08 | 5.27 | 2.99 | 2.11 | 6.31 | 5.60 | 4.23 |
| TOTAL CDF | 749.32 | 1818.93 | 1127.71 | 287.64 | 1372.76 | 1165.06 | 1086.90 |
| TOTAL CDD/CDF | 1166.45 | 2151.23 | 1353.99 | 409.45 | 1729.60 | 1529.23 | 1389.99 |

ATTACHMENT C
SEMI-VOLATILE RESULTS

TABLE C-1. RAW ANALYTICAL DATA FOR SEMI-VOLATILE ORGANICS
AT THE CONTROL DEVICE INLET

| SEMI-VOLATILES DETECTED (ng) | | | | |
|------------------------------|--------|--------|--------|---------|
| COMPOUND | RUN 01 | RUN 02 | RUN 03 | AVERAGE |
| ACID COMPOUNDS | | | | |
| 2-CHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DICHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DIMETHYLPHENOL | ND | ND | ND | NA |
| 2,6-DINITRO-O-CRESOL | ND | ND | ND | NA |
| 2,4-DINITROPHENOL | ND | ND | ND | NA |
| 2-NITROPHENOL | ND | ND | ND | NA |
| 4-NITROPHENOL | ND | ND | ND | NA |
| p-CHLORO-m-CRESOL | ND | ND | ND | NA |
| PENTACHLOROPHENOL | ND | ND | ND | NA |
| PHENOL | 3.5 | 7.7 | 9.8 | 7.0 |
| 2,4,6-TRICHLOROPHENOL | ND | ND | ND | NA |
| BASE COMPOUNDS | | | | |
| ACENAPTHENE | ND | ND | ND | NA |
| BENZO(a)PYRENE | ND | ND | ND | NA |
| BIS(2-ETHYLHEXYL)PHTHALATE | ND | ND | ND | NA |
| 1,2-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,3-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,4-DICHLOROBENZENE | ND | ND | ND | NA |
| NAPHTHALENE | 1.3 | 3.8 | 4.0 | 3.0 |
| PERCHLOROETHYLENE | ND | ND | ND | NA |
| 1,2,4-TRICHLOROBENZENE | ND | ND | ND | NA |
| PCBs and PESTICIDES | | | | |
| ALDRIN | ND | ND | ND | NA |
| CHLORODANE | ND | ND | ND | NA |
| DIELDRIN | ND | ND | ND | NA |
| PCB-1242 | ND | ND | ND | NA |
| PCB-1254 | ND | ND | ND | NA |
| PCB-1221 | ND | ND | ND | NA |
| PCB-1232 | ND | ND | ND | NA |
| PCB-1248 | ND | ND | ND | NA |
| PCB-1260 | ND | ND | ND | NA |
| PCB-1016 | ND | ND | ND | NA |

TABLE C-2. CONCENTRATION THE OF SEMI-VOLATILE ORGANICS IN THE CONTROL DEVICE INLET FLUE GAS

| CONCENTRATION (ng/dscm) | | | | |
|----------------------------|--------|--------|--------|---------|
| COMPOUND | RUN 01 | RUN 02 | RUN 03 | AVERAGE |
| ACID COMPOUNDS | | | | |
| 2-CHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DICHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DIMETHYLPHENOL | ND | ND | ND | NA |
| 2,6-DINITRO-O-CRESOL | ND | ND | ND | NA |
| 2,4-DINITROPHENOL | ND | ND | ND | NA |
| 2-NITROPHENOL | ND | ND | ND | NA |
| 4-NITROPHENOL | ND | ND | ND | NA |
| p-CHLORO-m-CRESOL | ND | ND | ND | NA |
| PENTACHLOROPHENOL | ND | ND | ND | NA |
| PHENOL | 2.3 | 4.5 | 5.7 | 4.2 |
| 2,4,6-TRICHLOROPHENOL | ND | ND | ND | NA |
| BASE COMPOUNDS | | | | |
| ACENAPTHENE | ND | ND | ND | NA |
| BENZO(a)PYRENE | ND | ND | ND | NA |
| BIS(2-ETHYLHEXYL)PHTHALATE | ND | ND | ND | NA |
| 1,2-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,3-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,4-DICHLOROBENZENE | ND | ND | ND | NA |
| NAPHTHALENE | 0.8 | 2.2 | 2.3 | 1.8 |
| PERCHLOROETHYLENE | ND | ND | ND | NA |
| 1,2,4-TRICHLOROBENZENE | ND | ND | ND | NA |
| PCBs and PESTICIDES | | | | |
| ALDRIN | ND | ND | ND | NA |
| CHLORODANE | ND | ND | ND | NA |
| DIELDRIN | ND | ND | ND | NA |
| PCB-1242 | ND | ND | ND | NA |
| PCB-1254 | ND | ND | ND | NA |
| PCB-1221 | ND | ND | ND | NA |
| PCB-1232 | ND | ND | ND | NA |
| PCB-1248 | ND | ND | ND | NA |
| PCB-1260 | ND | ND | ND | NA |
| PCB-1016 | ND | ND | ND | NA |

TABLE C-3. SEMI-VOLATILE ORGANIC MASS FLOW RATE AT THE CONTROL DEVICE INLET

| MASS FLOW RATES (ug/hr) | | | | |
|----------------------------|--------|--------|--------|---------|
| COMPOUND | RUN 01 | RUN 02 | RUN 03 | AVERAGE |
| ACID COMPOUNDS | | | | |
| 2-CHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DICHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DIMETHYLPHENOL | ND | ND | ND | NA |
| 2,6-DINITRO-O-CRESOL | ND | ND | ND | NA |
| 2,4-DINITROPHENOL | ND | ND | ND | NA |
| 2-NITROPHENOL | ND | ND | ND | NA |
| 4-NITROPHENOL | ND | ND | ND | NA |
| p-CHLORO-m-CRESOL | ND | ND | ND | NA |
| PENTACHLOROPHENOL | ND | ND | ND | NA |
| PHENOL | 15.2 | 33.6 | 41.5 | 30.1 |
| 2,4,6-TRICHLOROPHENOL | ND | ND | ND | NA |
| BASE COMPOUNDS | | | | |
| ACENAPHTHENE | ND | ND | ND | NA |
| BENZO(a)PYRENE | ND | ND | ND | NA |
| BIS(2-ETHYLHEXYL)PHTHALATE | ND | ND | ND | NA |
| 1,2-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,3-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,4-DICHLOROBENZENE | ND | ND | ND | NA |
| NAPHTHALENE | 5.6 | 16.6 | 17.0 | 13.1 |
| PERCHLOROETHYLENE | ND | ND | ND | NA |
| 1,2,4-TRICHLOROBENZENE | ND | ND | ND | NA |
| PCBs and PESTICIDES | | | | |
| ALDRIN | ND | ND | ND | NA |
| CHLORODANE | ND | ND | ND | NA |
| DIELDRIN | ND | ND | ND | NA |
| PCB-1242 | ND | ND | ND | NA |
| PCB-1254 | ND | ND | ND | NA |
| PCB-1221 | ND | ND | ND | NA |
| PCB-1232 | ND | ND | ND | NA |
| PCB-1248 | ND | ND | ND | NA |
| PCB-1260 | ND | ND | ND | NA |
| PCB-1016 | ND | ND | ND | NA |

TABLE C-4. RAW ANALYTICAL DATA FOR SEMI-VOLATILE ORGANICS
IN THE SLUDGE FEED

| SEMI-VOLATILES DETECTED (ng/kg) | | | | |
|---------------------------------|--------|--------|--------|---------|
| COMPOUND | RUN 01 | RUN 02 | RUN 03 | AVERAGE |
| ACID COMPOUNDS | | | | |
| 2-CHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DICHLOROPHENOL | ND | ND | ND | NA |
| 2,4-DIMETHYLPHENOL | ND | ND | ND | NA |
| 2,6-DINITRO-O-CRESOL | ND | ND | ND | NA |
| 2,4-DINITROPHENOL | ND | ND | ND | NA |
| 2-NITROPHENOL | ND | ND | ND | NA |
| 4-NITROPHENOL | ND | ND | ND | NA |
| p-CHLORO-m-CRESOL | ND | ND | ND | NA |
| PENTACHLOROPHENOL | ND | ND | ND | NA |
| PHENOL | 0.7 | ND | ND | NA |
| 2,4,6-TRICHLOROPHENOL | ND | ND | ND | NA |
| BASE COMPOUNDS | | | | |
| ACENAPHTHENE | ND | ND | ND | NA |
| BENZO(a)PYRENE | ND | ND | ND | NA |
| BIS(2-ETHYLHEXYL)PHTHALATE | 19 | 23 | 22 | 21 |
| 1,2-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,3-DICHLOROBENZENE | ND | ND | ND | NA |
| 1,4-DICHLOROBENZENE | ND | ND | ND | NA |
| NAPHTHALENE | 1.6 | 1.6 | 1.4 | 1.5 |
| PERCHLOROETHYLENE | ND | ND | ND | NA |
| 1,2,4-TRICHLOROBENZENE | ND | ND | ND | NA |
| PCBs and PESTICIDES | | | | |
| ALDRIN | ND | ND | ND | NA |
| CHLOROBANE | ND | ND | ND | NA |
| DIELDRIN | ND | ND | ND | NA |
| PCB-1242 | ND | ND | ND | NA |
| PCB-1254 | ND | ND | ND | NA |
| PCB-1221 | ND | ND | ND | NA |
| PCB-1232 | ND | ND | ND | NA |
| PCB-1248 | ND | ND | ND | NA |
| PCB-1260 | ND | ND | ND | NA |
| PCB-1016 | ND | ND | ND | NA |



ATTACHMENT D
METALS RESULTS

TABLE D-1. RAW ANALYTICAL DATA FOR THE SLUDGE FEED SAMPLES
COLLECTED DURING THE M12 INLET RUNS

| ===== | | | | | | |
|------------------------|--------|--------|--------|--------|--------|---------|
| AMOUNT DETECTED (ug/g) | | | | | | |
| METAL | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | AVERAGE |
| ===== | | | | | | |
| ARSENIC(As) | 3.2 | 3.1 | 2.4 | 2.5 | 2.6 | 2.8 |
| BERYLIUM(Be) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| CADMIUM(Cd) | 11 | 11 | 15 | 15 | 15 | 13 |
| CHROMIUM(Cr) | 66 | 70 | 73 | 71 | 68 | 70 |
| COPPER(Cu) | 740 | 720 | 840 | 840 | 770 | 782 |
| LEAD(Pb) | 290 | 270 | 380 | 360 | 370 | 334 |
| NICKEL(Ni) | 210 | 170 | 340 | 370 | 290 | 276 |
| SELLENIUM(Se) | 0.9 | 1.1 | 1.4 | 1.4 | 1.3 | 1.2 |
| ZINC(Zn) | 630 | 610 | 690 | 660 | 620 | 642 |
| ===== | | | | | | |

TABLE D-2. RAW ANALYTICAL DATA FOR THE SCRUBBER WATER INFLUENT
SAMPLES COLLECTED DURING THE M12 INLET RUNS

| ===== | | | | | | |
|------------------------|--------|--------|--------|--------|--------|---------|
| AMOUNT DETECTED (ug/l) | | | | | | |
| METAL | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | AVERAGE |
| ===== | | | | | | |
| ARSENIC(As) | ND | ND | ND | ND | ND | NA |
| BERYLIUM(Be) | ND | ND | ND | ND | ND | NA |
| CADMIUM(Cd) | 4 | ND | ND | ND | ND | NA |
| CHROMIUM(Cr) | ND | ND | ND | ND | ND | NA |
| LEAD(Pb) | 5 | 4 | 4 | 4 | 5 | 4 |
| NICKEL(Ni) | 130 | 100 | 240 | 220 | 250 | 188 |
| ===== | | | | | | |

TABLE D-3. RAW ANALYTICAL DATA FOR THE SCRUBBER WATER EFFLUENT
 SAMPLES COLLECTED DURING THE M12 INLET RUNS

| AMOUNT DETECTED (ug/l) | | | | | | |
|------------------------|--------|--------|--------|--------|--------|---------|
| METAL | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | AVERAGE |
| ARSENIC(As) | 9 | 5 | 30 | ND | ND | 15 |
| BERYLIUM(Be) | ND | ND | 250 | 3 | 190 | 148 |
| CADMIUM(Cd) | 110 | 110 | 110 | 80 | 80 | 98 |
| CHROMIUM(Cr) | 120 | 70 | 50 | 20 | 20 | 56 |
| LEAD(Pb) | 1600 | 2000 | 1100 | 950 | 800 | 1290 |
| NICKEL(Ni) | 530 | 250 | 350 | 290 | 310 | 346 |

TABLE D-4. RAW ANALYTICAL DATA FOR METALS FOR THE BOTTOM ASH
 SAMPLES COLLECTED DURING THE M12 INLET RUNS

| AMOUNT DETECTED (ug/g) | | | | | | |
|------------------------|--------|--------|--------|--------|--------|---------|
| METAL | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | AVERAGE |
| ARSENIC(As) | 9.5 | 9.5 | 11 | 24 | 23 | 15 |
| BERYLIUM(Be) | 0.4 | 0.5 | 0.5 | 0.8 | 0.6 | 0.6 |
| CADMIUM(Cd) | 0.8 | 1.4 | ND | ND | ND | NA |
| CHROMIUM(Cr) | 160 | 190 | 210 | 200 | 180 | 188 |
| COPPER(Cu) | 1700 | 1600 | 2200 | 2000 | 2000 | 1900 |
| LEAD(Pb) | 280 | 120 | 170 | 150 | 230 | 190 |
| NICKEL(Ni) | 500 | 420 | 940 | 890 | 760 | 702 |
| SELLENIUM(Se) | 0.8 | 0.8 | 0.7 | 1.3 | 1.1 | 0.9 |
| ZINC(Zn) | 1100 | 1100 | 750 | 760 | 1000 | 942 |

TABLE D-5. RAW ANALYTICAL DATA FOR THE SLUDGE FEED SAMPLES COLLECTED DURING THE M12 OUTLET RUNS

| METAL | AMOUNT DETECTED (ug/g) | | | | | | | | | | | |
|----------------|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | RUN 10 | RUN 11 | AVERAGE |
| ARSENIC (As) | 2.6 | 3.2 | 3.2 | 3.1 | 2.9 | 2.7 | 2.5 | 2.4 | 2.5 | 2.6 | 2.2 | 2.7 |
| BERYLLIUM (Be) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| CADMIUM (Cd) | 8.6 | 11 | 11 | 11 | 13 | 14 | 15 | 15 | 15 | 15 | 15 | 13 |
| CHROMIUM (Cr) | 62 | 66 | 66 | 70 | 74 | 71 | 76 | 73 | 71 | 68 | 63 | 69 |
| COPPER (Cu) | 740 | 740 | 710 | 720 | 840 | 830 | 880 | 840 | 840 | 770 | 840 | 795 |
| LEAD (Pb) | 240 | 290 | 270 | 270 | 170 | 510 | 380 | 380 | 360 | 370 | 360 | 327 |
| NICKEL (Ni) | 280 | 210 | 210 | 170 | 140 | 420 | 440 | 340 | 370 | 290 | 310 | 289 |
| SELLENIUM (Se) | 0.8 | 0.9 | 0.9 | 1.1 | 1.4 | 1.2 | 1.4 | 1.4 | 1.4 | 1.3 | 1.2 | 1.2 |
| ZINC (Zn) | 600 | 630 | 620 | 610 | 680 | 660 | 700 | 690 | 660 | 620 | 650 | 647 |

TABLE D-6. RAW ANALYTICAL DATA FOR THE SCRUBBER WATER INFLUENT SAMPLES COLLECTED DURING THE M12 OUTLET RUNS

| ===== | | | | | | | | | | |
|------------------------|--------|--------|--------|--------|--------|--------|--------|---------|----|----|
| AMOUNT DETECTED (ug/l) | | | | | | | | | | |
| ----- | | | | | | | | | | |
| METAL | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 08 | RUN 09 | RUN 10 | AVERAGE | | |
| ----- | | | | | | | | | | |
| ARSENIC (As) | ND | NA | NA |
| BERYLLIUM (Be) | ND | NA | NA |
| CADMIUM (Cd) | ND | 4 | ND | ND | ND | ND | ND | ND | NA | NA |
| CHROMIUM (Cr) | ND | NA | NA |
| LEAD (Pb) | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 |
| NICKEL (Ni) | 170 | 130 | 120 | 100 | 240 | 220 | 250 | 176 | | |
| ===== | | | | | | | | | | |

TABLE D-7. RAM ANALYTICAL DATA FOR THE SCRUBBER WATER EFFLUENT SAMPLES COLLECTED DURING THE #12 OUTLET RUNS

| ===== | | | | | | | | | | |
|------------------------|--------|--------|--------|--------|--------|--------|--------|---------|-------|--|
| AMOUNT DETECTED (ug/l) | | | | | | | | | | |
| ----- | | | | | | | | | | |
| METAL | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 08 | RUN 09 | RUN 10 | AVERAGE | ===== | |
| ARSENIC (As) | ND | 9 | 10 | 5 | 30 | ND | ND | 14 | ===== | |
| BERYLLIUM (Be) | ND | ND | ND | ND | 250 | 3 | 1900 | 718 | ===== | |
| CADMIUM (Cd) | 30 | 110 | 80 | 110 | 110 | 80 | 80 | 86 | ===== | |
| CHROMIUM (Cr) | 30 | 120 | 150 | 70 | 50 | 20 | 20 | 66 | ===== | |
| LEAD (Pb) | 250 | 1600 | 1300 | 2000 | 1100 | 950 | 800 | 1143 | ===== | |
| NICKEL (Ni) | 340 | 530 | 580 | 250 | 350 | 290 | 310 | 379 | ===== | |

TABLE D-8. RAW ANALYTICAL DATA FOR THE BOTTOM ASH SAMPLES COLLECTED DURING THE M12 OUTLET RUNS

| ===== | | | | | | | | | | |
|------------------------|--------|--------|--------|--------|--------|--------|--------|---------|--|--|
| AMOUNT DETECTED (ug/g) | | | | | | | | | | |
| ----- | | | | | | | | | | |
| METAL | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 08 | RUN 09 | RUN 10 | AVERAGE | | |
| ===== | | | | | | | | | | |
| ARSENIC(As) | 9.5 | 9.5 | 8.5 | 9.5 | 11 | 24 | 23 | 14 | | |
| BERYLLIUM(Be) | 0.5 | 0.4 | 0.3 | 0.5 | 0.5 | 0.8 | 0.6 | 0.5 | | |
| CADMIUM(Cd) | 0.6 | 0.8 | 0.7 | 1.4 | ND | ND | ND | 0.5 | | |
| CHROMIUM(Cr) | 150 | 160 | 150 | 190 | 210 | 200 | 180 | 177 | | |
| COPPER(Cu) | 1800 | 1700 | 1500 | 1600 | 2200 | 2000 | 2000 | 1829 | | |
| LEAD(Pb) | 300 | 280 | 290 | 120 | 170 | 150 | 230 | 220 | | |
| NICKEL(Ni) | 710 | 500 | 430 | 420 | 940 | 890 | 760 | 664 | | |
| SELLENIUM(Se) | 0.9 | 0.8 | 0.8 | 0.8 | 0.7 | 1.3 | 1.1 | 0.9 | | |
| ZINC(Zn) | 1200 | 1100 | 1100 | 1100 | 750 | 760 | 1000 | 1001 | | |
| ===== | | | | | | | | | | |



A.3 PRELIMINARY FLUE GAS METAL RESULTS, JANUARY 11, 1988

RADIAN

CORPORATION

January 11, 1988

Dr. Harry Bostian
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
26 W. St. Clair Street
Cincinnati, Ohio 45268

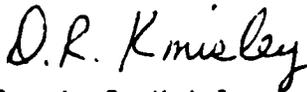
Dear Harry:

Enclosed are the last of the preliminary results for the fourth Sewage Sludge Test at Cranston, Rhode Island. Included in this letter are the flue gas metal results for the runs conducted at the inlet and outlet of the control device. The metals results for the scrubber water influent, scrubber water effluent, and bottom ash were included in the letter dated December 22, 1987.

Table 1 is a summary of the number of runs conducted and the incinerator operating conditions during each run. The control device inlet metals results are presented in Tables 2, 3, and 4 while the control device outlet flue gas results are shown in Tables 5, 6 and 7. The results of the field blank trains are shown in Table 8. It should be noted that the chromium results in the field blank were very high for both the inlet and outlet samples. The chromium results for the Method 12 runs are presented for comparison only. We are awaiting the internal audit results before we can determine the source of the chromium contamination.

If you have any questions concerning these results or need any additional information, please contact me at (919) 481-0212.

Sincerely,



Dennis R. Knisley,
Chemical Engineer

DRK/lrs

cc: Gene Crumpler, U.S. EPA
Robert Dykes, Radian
Keith Barnett, Radian
Mike Palazzolo, Radian
Mike Lewis, Technical Consultant

ess/004

TABLE 1. SUMMARY OF THE INCINERATOR OPERATING CONDITIONS FOR THE METHOD 12 TESTS CONDUCTED DURING THE FOURTH SEWAGE SLUDGE TEST^a

| Run No. | Sampling Location | Incinerator Operating Conditions |
|-----------------------|-----------------------|----------------------------------|
| M12 - 02 | Control Device Inlet | Cool Furnace, Afterburner Off |
| M12 - 04 ^b | | Hot Furnace, Afterburner On |
| M12 - 06 ^b | | Cool Furnace, Afterburner Off |
| M12 - 07 ^b | | Cool Furnace, Afterburner Off |
| M12 - 08 ^b | | Cool Furnace, Afterburner Off |
| M12 - 01 | Control Device Outlet | Cool Furnace, Afterburner Off |
| M12 - 02 | | Cool Furnace, Afterburner Off |
| M12 - 03 | | Hot Furnace, Afterburner On |
| M12 - 04 ^b | | Hot Furnace, Afterburner On |
| M12 - 05 | | Cool Furnace, Afterburner Off |
| M12 - 06 | | Hot Furnace, Afterburner Off |
| M12 - 07 | | Hot Furnace, Afterburner Off |
| M12 - 08 ^b | | Cool Furnace, Afterburner Off |
| M12 - 09 ^b | | Cool Furnace, Afterburner Off |
| M12 - 10 ^b | | Cool Furnace, Afterburner Off |
| M12 - 11 | | Hot Furnace, Afterburner Off |

^aThe "Cool Furnace" operating condition is characterized by a combustion hearth temperature of 1100-1400°F while the "Hot Furnace" operating condition is characterized by a combustion hearth temperature of 1400-1700°F.

^bInlet Runs 04, 06, 07, and 08 were run concurrently with outlet Runs 04, 08, 09, and 10, respectively. The inlet run numbers will be changed to correspond to the outlet run numbers in the Site 04 Test Report to simplify the presentation of results.

ees/004

TABLE 2. RAW ANALYTICAL DATA FOR THE INLET METAL TRAINS

| ===== | | | | | | |
|----------------------|--------|--------|--------|--------|--------|---------|
| AMOUNT DETECTED (ug) | | | | | | |
| METAL | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | AVERAGE |
| ===== | | | | | | |
| a | | | | | | |
| ===== | | | | | | |
| ARSENIC(As) | 24 | 12 | 45 | 32 | 35 | 37 |
| BERYLIUM(Be) | ND | ND | ND | ND | ND | NA |
| CADMIUM(Cd) | 760 | 638 | 720 | 763 | 684 | 722 |
| CHROMIUM(Cr) | 1920 | 357 | 975 | 429 | 793 | 732 |
| LEAD(Pb) | 2080 | 12395 | 11250 | 7440 | 7070 | 8587 |
| NICKEL(Ni) | 1840 | 402 | 548 | 1052 | 800 | 800 |

a The average only includes Run 06-08. Run 02 did not meet isokinetic specifications and Run 04 was conducted under different operating conditions.

TABLE 3. METAL CONCENTRATION IN THE CONTROL DEVICE INLET FLUE FLUE GAS SAMPLES

| ===== | | | | | | |
|-------------------------|--------|--------|--------|--------|--------|---------|
| CONCENTRATION (ug/dscf) | | | | | | |
| METAL | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | AVERAGE |
| ===== | | | | | | |
| a | | | | | | |
| ===== | | | | | | |
| ARSENIC(As) | 11 | 7.8 | 30 | 23 | 21 | 25 |
| BERYLIUM(Be) | ND | ND | ND | ND | ND | NA |
| CADMIUM(Cd) | 352 | 407 | 476 | 555 | 417 | 483 |
| CHROMIUM(Cr) | 890 | 234 | 645 | 312 | 484 | 480 |
| LEAD(Pb) | 965 | 7914 | 7440 | 5409 | 4315 | 5721 |
| NICKEL(Ni) | 853 | 257 | 362 | 765 | 488 | 538 |

a The average only includes Run 06-08. Run 02 did not meet isokinetic specifications and Run 04 was conducted under different operating conditions.

TABLE 4. METAL MASS FLOW RATES AT THE CONTROL DEVICE INLET

| METAL | MASS FLOW RATE (mg/hr) | | | | | AVERAGE ^a |
|---------------|------------------------|--------|--------|--------|--------|----------------------|
| | RUN 02 | RUN 04 | RUN 06 | RUN 07 | RUN 08 | |
| ARSENIC (As) | 98 | 56 | 192 | 145 | 146 | 161 |
| BERYLIUM (Be) | ND | ND | ND | ND | ND | NA |
| CADMIUM (Cd) | 2789 | 2928 | 3071 | 3466 | 2888 | 3142 |
| CHROMIUM (Cr) | 7047 | 1684 | 4159 | 1949 | 3348 | 3152 |
| LEAD (Pb) | 7634 | 56891 | 47988 | 33798 | 29849 | 37212 |
| NICKEL (Ni) | 6753 | 1845 | 2338 | 4779 | 3378 | 3498 |

^a The average only includes Run 05-08. Run 02 did not meet isokinetic specifications and Run 04 was conducted under different operating conditions.

g/hr

0.16

TABLE 5. RAW ANALYTICAL DATA FOR THE OUTLET METAL TRAINS

| METAL | AMOUNT DETECTED (ug) | | | | | | | | | | | AVERAGE | | |
|----------------|----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|------|------|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | RUN 10 | RUN 11 | a | b | c |
| ARSENIC (As) | 4.5 | 4.0 | 4.8 | 6.8 | 5.9 | 4.8 | 6.4 | 5.6 | 6.8 | 6.0 | 5.2 | 5.5 | 5.8 | 5.5 |
| BERYLLIUM (Be) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| CADMIUM (Cd) | 225 | 296 | 224 | 391 | 462 | 264 | 384 | 312 | 391 | 408 | 351 | 347 | 308 | 333 |
| CHROMIUM (Cr) | 570 | 584 | 576 | 723 | 572 | 328 | 616 | 536 | 706 | 782 | 592 | 625 | 650 | 512 |
| COPPER (Cu) | 467 | 584 | 416 | 1190 | 715 | 880 | 1360 | 640 | 935 | 842 | 1040 | 697 | 803 | 1093 |
| LEAD (Pb) | 1725 | 3040 | 2000 | 7820 | 4680 | 4160 | 11200 | 3520 | 4590 | 6460 | 5070 | 4003 | 4910 | 6810 |
| NICKEL (Ni) | 90 | 48 | 56 | 34 | 46 | 40 | 128 | 40 | 50 | 51 | 72 | 56 | 45 | 80 |
| SELLENIUM (Se) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| ZINC (Zn) | 3300 | 3840 | 2640 | 2890 | 7150 | 4720 | 7360 | 6240 | 7990 | 7820 | 8450 | 6057 | 2765 | 6643 |

a Cool furnace, afterburner off (Runs 01,02,05,08,09,10)

b Hot furnace, afterburner on (Runs 03,04)

c Hot furnace, afterburner off (Runs 06,07,11)

TABLE 6. METAL CONCENTRATIONS IN THE CONTROL DEVICE OUTLET FLUE GAS SAMPLES

| METAL | CONCENTRATION (ug/dscm) | | | | | | | | | | | AVERAGE | | |
|---------------|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|------|------|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | RUN 10 | RUN 11 | a | b | c |
| ARSENIC(As) | 1.95 | 1.96 | 2.24 | 3.43 | 2.75 | 2.06 | 2.67 | 2.26 | 2.56 | 2.68 | 2.07 | 2.38 | 2.84 | 2.27 |
| BERYLLIUM(Be) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| CADMIUM(Cd) | 98 | 145 | 105 | 197 | 215 | 113 | 160 | 126 | 154 | 183 | 140 | 153 | 151 | 138 |
| CHROMIUM(Cr) | 248 | 286 | 269 | 365 | 266 | 141 | 257 | 216 | 278 | 350 | 235 | 274 | 317 | 211 |
| COPPER(Cu) | 203 | 286 | 194 | 601 | 333 | 377 | 567 | 258 | 369 | 377 | 415 | 304 | 358 | 453 |
| LEAD(Pb) | 749 | 1488 | 933 | 3949 | 2180 | 1783 | 4673 | 1419 | 1809 | 2890 | 2022 | 1756 | 2441 | 2826 |
| NICKEL(Ni) | 39.1 | 23.5 | 26.1 | 17.2 | 21.4 | 17.1 | 53.4 | 16.1 | 23.7 | 22.8 | 28.7 | 24.4 | 21.7 | 33.1 |
| SELLENIUM(Se) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA | NA |
| ZINC(Zn) | 1433 | 1680 | 1232 | 1459 | 3330 | 2023 | 3071 | 2516 | 3150 | 3498 | 3371 | 2635 | 1346 | 2622 |

a Cool furnace, afterburner off (Runs 01,02,05,08,09,10)

b Hot furnace, afterburner on (Runs 03,04)

c Hot furnace, afterburner off (Runs 06,07,11)

TABLE 7. METAL EMISSION RATES AT THE OUTLET

| METAL | EMISSION RATE (ug/hr) | | | | | | | | | | | AVERAGE | AVERAGE | AVERAGE |
|---------------|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | RUN 10 | RUN 11 | | | |
| ARSENIC(As) | 21 | 18 | 22 | 31 | 26 | 21 | 29 | 25 | 30 | 27 | 23 | 25 | 27 | 24 |
| BERYLLIUM(Be) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA |
| CADMIUM(Cd) | 1048 | 1353 | 1023 | 1793 | 2036 | 1171 | 1714 | 1388 | 1738 | 1632 | 1559 | 1566 | 1408 | 1481 |
| CHROMIUM(Cr) | 2654 | 2669 | 2630 | 3316 | 2521 | 1455 | 2749 | 2385 | 3138 | 3510 | 2629 | 2813 | 2973 | 2278 |
| COPPER(Cu) | 2175 | 2669 | 1900 | 5458 | 3151 | 3903 | 6070 | 2847 | 4156 | 3780 | 4618 | 3130 | 3679 | 4854 |
| LEAD(Pb) | 8033 | 13894 | 9133 | 35866 | 20625 | 18450 | 49985 | 15659 | 20401 | 28999 | 22514 | 17935 | 22500 | 30316 |
| NICKEL(Ni) | 419 | 219 | 256 | 156 | 203 | 177 | 571 | 178 | 267 | 229 | 320 | 252 | 206 | 356 |
| SELLENIUM(Se) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | NA | NA |
| ZINC(Zn) | 15367 | 17550 | 12056 | 13255 | 31510 | 20934 | 32847 | 27760 | 35513 | 35104 | 37523 | 27134 | 12655 | 30435 |

a Cool furnace, afterburner off (Runs 01,02,05,08,09,10)

b Hot furnace, afterburner on (Runs 03,04)

c Hot furnace, afterburner off (Runs 06,07,11)

TABLE 2. RAW ANALYTICAL DATA FOR THE
METAL FIELD BLANKS

| METAL | AMOUNT DETECTED (ug) | |
|---------------|-------------------------|--------------------------|
| | INLET FIELD BLANK | OUTLET FIELD BLANK |
| ARSENIC (As) | ND | 6 |
| BERYLIUM (Be) | ND | ND |
| CADMIUM (Cd) | 7 | 4 |
| CHROMIUM (Cr) | 704 | 624 |
| COPPER (Cu) | | 24 |
| LEAD (Pb) | 64 | 40 |
| NICKEL (Ni) | 24 | 16 |
| SELENIUM (Se) | | ND |
| ZINC (Zn) | | 48 |

RADIANAUDIT REPORT

11 January 1988

232-009-71-12

303-404-04-01

TO: Distribution
FROM: K.W. Rozacky
PROJECT: Sewage Sludge Incineration (SSI) Program
Chemistry Division Internal Audit Program
SUBJECT: October 1987 Performance Audit Sample Results

1.0 INTRODUCTION

On October 7, 1987 performance audit samples were prepared and submitted to the analytical task leader, Keith Barnett, for distribution to laboratories conducting analyses for the Sewage Sludge Incineration (SSI) Program. Samples simulating flue gas impinger catches and scrubber effluents were submitted to Radian's Sacramento Production Chemistry (SPC) Laboratory and Perimeter Park (PPK) Laboratory. Due to budget constraints, not all samples were submitted for analysis. This audit qualifies for consideration as part of the the Chemistry Division Internal Audit Program. Results for the audit samples are assumed to be representative of the quality of the data for similar samples analyzed during the same time period. Analytical performance was assessed for the following methods:

- Purgeable Organics in water samples by EPA Method 8240 analysed at SPC;
- Semi-Volatile Acid & Base Neutral Extractable Organics in water by EPA Method 8270 analysed at PPK;
- Pesticides and PCB's in water samples by EPA Method 8080 analysed at PPK;

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- Chromium +6 in water samples by EPA Method 7196 analyzed at PPK;
- Metals in water by EPA Methods 6010, 7060, 7421, and 7740 analyzed at SPC; and
- Metals on glass fiber filter media by EPA Methods 6010, 7060, 7421, and 7740 analyzed at SPC.

2.0 RECOMMENDATIONS FOR CORRECTIVE ACTION

No formal recommendations for corrective action are required at this time.



3.0 DISCUSSION

The audit or performance evaluation (PE) samples used for the October 1987 laboratory performance audits were submitted as sets of three samples except for the glass fiber filter sample. Each set of three samples consisted of a matrix blank and two samples spiked at levels representative of expected SSI field samples. Audit samples were prepared by spiking U.S. EPA Quality Control Check Materials, NBS SRMs or standards prepared from neat materials into laboratory pure matrices.

A summary of major problems revealed by these audit samples included:

- Perimeter Park (PPK) Laboratory:
 - False positive results reported for 1,4-dichlorobenzene, bis (2-ethyl hexyl) phthalate and benzo(a)pyrene in the water matrix blank sample B/N extract analysed by EPA Method 8270. Analytical data for field samples may indicate the same compounds as present. There is a possibility that the results are due to contribution from an outside source.
 - No recovery of B/N target analytes where analytes present in sample at >2 times the expected detection limits. This occurred in only one of the water matrix samples analysed by Method 8270. Possibility exists for analytes to be present in field samples but not be detected.
 - False positive results reported for 2-nitrophenol, 2,4,6-trichlorophenol and 4-nitrophenol in the water matrix blank ACID extract analysed by EPA Method 8270.



Analytical data for field samples may indicate the same compounds as present. There is a possibility that the results are due to contribution from an outside source.

-- No recovery of ACID target analytes where analytes are present in sample at >2 times the expected detection limits. Phenol is the only target analyte that did not seem to be impacted. This occurred in only one of the water matrix samples analyzed by Method 8270. The possibility exists for analytes to be present in field samples but not be detected.

• Sacramento Production Chemistry:

-- High recovery, approximately 2 times (161% to 275%), for metals on glass fiber filter media analyzed by Methods 6010, 7060, 7421, and 7740. Possibility exists that the digestate volume was incorrectly reported OR THAT THE FILTER MEDIA HAS A BACKGROUND LEVELS OF THE ANALYTE OF INTEREST.



3.1 Purgeable Organics in Water Samples by EPA Method 8240

Performance evaluation samples of water matrices were prepared and submitted to SPC for analysis by EPA Method 8240. Samples containing five of the SSI analytes of interest, spiked at concentrations from 4 to 28 times the expected method detection limit, and a matrix blank sample were submitted. At the direction of the analytical task leader, Sample 3, one of the spiked samples, was not analyzed. The matrix was purified water that had been boiled and purged with URP helium. No problems were indicated by the reported results which are presented in Table 1.

Results for Sample 1 indicate correct identification of all five of the target analytes. Of the target analytes, benzene and toluene were quantitated outside the accuracy objectives as specified in Method 8240, and adopted as the accuracy objectives for the SSI Program. This performance is not considered problematic to the utility of the data since the recoveries were just outside the objectives. Only one additional compound, methylene chloride (4 ug/L), was reported as a false positive in this sample. No target analytes were reported as present in the matrix blank sample. If the other field sample results indicate low levels of methylene chloride to be present, contribution from an outside source should be considered when interpreting the data.



3.2 Semi-Volatile Organics in Water Samples by EPA Method 8270

Performance evaluation samples of water matrices were prepared and submitted to PPK for analysis by EPA Method 8270. A matrix blank and two spiked samples were submitted. Two major problems were identified that impact both acid and base neutral extract analyses. One problem was that several unexpected compounds were reported as present in the matrix blank samples and the other problem was that target compounds present at representative levels were not detected.

Results for the base neutral (B/N) extractable organics are presented in Table 2. False positive results were reported for 1,4-dichlorobenzene (4 ug/L), bis (2-ethyl hexyl) phthalate (5 ug/L) and benzo(a)pyrene (7 ug/L) in the water matrix blank sample B/N extract analyzed by EPA Method 8270. Analytical data for field samples may indicate the same compounds as present. There is a possibility that the results are due to contribution from an outside source. This should be considered when interpreting the analytical data for similar samples.

B/N target analytes were not detected where analytes present in sample at >2 times the expected detection limits. This occurred in only one of the water matrix samples analyzed by Method 8270. Only one, bis (2-ethyl hexyl) phthalate, of the five target analytes contained in Sample 3 was identified. This compound was also reported as present in the matrix blank sample. Of the five target analytes contained in Sample 1 all five were correctly identified and only one was quantitated outside the expected range of recovery. The concentrations of analytes in Sample 1 were half of the concentrations of the same analytes present in Sample 3. The possibility exists for analytes to be present in field samples but not be detected.

Results for the acid extractable semi-volatile organics are presented in Table 3. False positive results reported for 2-nitrophenol (14 ug/L), 2,4,6-trichlorophenol (12 ug/L) and 4-nitrophenol (6 ug/L) in the water matrix blank ACID extract analyzed by EPA Method 8270. Analytical

RADIAN
CORPORATION

data for field samples may indicate the same compounds as present. There is a possibility that the results are due to contribution from an outside source. This should be considered when interpreting the analytical data for similar samples.

WAS NOT DETECTED

~~No recovery~~ of ACID target analytes where analytes are present in sample at >2 times the expected detection limits. This problem occurred in only one of the water matrix samples analyzed by Method 8270. Phenol is the only target analyte that did not seem to be impacted. Sample 1 contained ten of the semi-volatile target analytes, including phenol. The only target analyte contained in Sample 3 was phenol. Phenol was the only target analyte reported as present in either of the spiked audit samples. The possibility exists for analytes to be present in field samples but not be detected.

RADIAN
CORPORATION**3.3 Pesticides and PCBs in Water by EPA 8080**

Tables 4 and 10 of this report present the audit values for samples submitted for assessment of Method 8080 performance. At the direction of the analytical task leader no Method 8080 analyses were conducted for liquid samples associated with this phase of the SSI testing. The tables are provided for additional information in the event that the semi-volatile organic sample extracts are analyzed for PCBs or pesticides.

3.4 Chromium + 6 in Water by Method 7196

Three sample containing chromium in the +6 valence state were submitted to PFK for analysis. The results for these analyses are presented in Table 5. No problems were indicated.

3.5 Metals in Water by EPA Methods 6010, 7060, 7421 and 7740

Three audit samples consisting of a matrix blank and two spiked samples were sent to SPC for metals determination by inductively coupled plasma emission spectroscopy (ICPES) analysis and atomic absorption (AA). Cadmium and chromium concentrations were determined by ICPES and the results are presented in Table 6. Lead, arsenic and selenium concentrations were determined by AA and the results are presented in Table 7. No analytes were reported at concentrations above the expected detection limits in the matrix blank sample. Quantitation for each target analyte was within +10% for ICPES analyses and +20% for AA analyses. No problems are indicated.

RADIAN
CORPORATION**3.6 Metals on Glass Fiber Filter Media by EPA Methods 6010, 7060, 7421 and 7740**

One audit sample consisting of a spiked glass fiber filter was sent to SPC for metals determination by inductively coupled plasma emission spectroscopy (ICPES) analysis and atomic absorption (AA). Beryllium, cadmium, chromium, copper, nickel and zinc concentrations were determined by ICPES and the results are presented in Table 8. Lead, arsenic and selenium concentrations were determined by AA and the results are presented in Table 9.

Two problems were identified by these results. An unexpected value for copper (70 ug/L) was reported. Copper was not one of the spiked analytes. The other problem was that analyte recoveries were all high, ranging from 161% to 275%. There are two possible explanations for this high recovery. One explanation would be that an incorrect digestate volume was reported by the laboratory. The other explanation might be that the filter media had background concentrations of the target analytes. Media blank analytical results should be reviewed to see if a background is present that would influence interpretation of the analytical data.

4.0 STATUS OF PREVIOUS RECOMMENDATIONS

The following tables present the status of previous recommendations for corrective action made to these laboratories.

TABLE 1. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR GC/MS ANALYSIS FOR PHENOLIC ORGANICS IN WATER SAMPLES - EPA METHOD 8240 - GC/MS (SFC - SACRAMENTO, CA)

| Parameter | Expected Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | 3 | | Matrix Blank Reported Value (ug/L) |
|---|---|---|--------------------|-----------------------|--------------------|-----------------------|------------------------------------|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Audit Value (ug/L) | Reported Value (ug/L) | |
| Tetrachloroethane | 5 | 64-148 | 35 | 124 | - ^d | NA | ND |
| Ethylbenzene | 5 | 37-162 | 55 | 39 | 139 | NA | ND |
| Chlorobenzene | 5 | 37-160 | 104 | 61 | - ^e | NA | ND |
| Benzene | 5 | 37-151 | 28 | 9.1 | 49 | NA | ND |
| Toluene | 5 | 47-150 | 55 | 23 | 142 | NA | ND |
| o-Xylene | 5 | NS | - ^e | NA | 126 | NA | ND |
| m-Xylene | 5 | NS | 28 | NA | 76 | NA | ND |
| p-Xylene | 5 | NS | - ^e | NA | 28 | NA | ND |
| Methylene Chloride | 5 | D-221 | - ^d | 4 | - ^e | NA | ND |
| <u>Surrogate Spike Recoveries^f</u> | | | | | | | |
| d ₄ -1,2-Dichloroethane | NS | 76-114 | 50 | NR | 50 | NA | 99 |
| d ₆ -Toluene | NS | 88-110 | 50 | NR | 50 | NA | 99 |
| p-Bromofluorobenzene | NS | 86-115 | 50 | NR | 50 | NA | 100 |

^aDetection Limit as published in Method 8240.

^bExpected range of recovery for spiked analytes in water matrix (Reference EPA Method 624).

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dNot contained in audit sample.

^eCannot be calculated or calculation not meaningful.

^fFor surrogate spikes expected range of recovery and audit value (spike level) taken from EPA GLP protocol.

D - Detected, result must be greater than zero.

FF - False Positive; analyte reported as present, but not contained in audit sample.

NS - Not Specified.

NR - Not Reported; laboratory routinely reports only the % recovery for spikes.

NA - Not Analyzed for.

ND - Not Detected.

FN - False Negative; analyte contained in audit sample, but not detected.

TABLE 2. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR SEMI-VOLATILE BASE/NEUTRAL EXTRACTABLE ORGANICS IN WATER SAMPLES - EPA METHOD 8270 - CC/NS (PEK - MORRISVILLE, NC)

| Parameter | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | 3 | | 2 | |
|------------------------------|--|---|--------------------|-----------------------|--------------------|-----------------------|--------------------|-----------------------|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Audit Value (ug/L) | Reported Value (ug/L) | Audit Value (ug/L) | Reported Value (ug/L) |
| 1,2-Dichlorobenzene | 10 | 32-129 | -f | ND | 42 | ND | ND | ND |
| 1,3-Dichlorobenzene | 10 | B-172 | -f | ND | -f | ND | ND | ND |
| 1,4-Dichlorobenzene | 10 | 20-124 | 12 | 9 | 25 | ND | 4 | 4 |
| 1,2,4-Trichlorobenzene | 10 | 44-142 | -f | ND | -f | ND | ND | ND |
| Naphthalene | 10 | 21-133 | 13 | 28 | 25 | ND | ND | ND |
| bis (2-Ethylhexyl Phthalate) | 10 | 8-158 | 8 | 11 | 15 | 4 | 5 | 5 |
| Acenaphthene | 10 | 47-145 | 10 | 13 | 20 | ND | ND | ND |
| Benzo(a)Pyrene | 10 | 17-163 | 11 | 13 | 22 | ND | 7 | 7 |
| Bis(2-chloroisopropyl)ether | 10 | 36-166 | 10 | NA | 20 | NA | NA | NA |
| Hexachloroethane | 10 | 40-113 | 15 | NA | 30 | NA | NA | NA |
| Nitrobenzene | 10 | 35-180 | 19 | NA | 37 | NA | NA | NA |
| Dimethyl Phthalate | 10 | D-112 | 20 | NA | 40 | NA | NA | NA |
| Fluorene | 10 | 59-121 | 13 | NA | 25 | NA | NA | NA |
| 4-Chlorophenyl phenyl ether | 10 | 25-158 | 19 | NA | 37 | NA | NA | NA |
| 4-Bromophenyl phenyl ether | 10 | 53-127 | 19 | NA | 37 | NA | NA | NA |
| Anthracene | 10 | 27-133 | 10 | NA | 20 | NA | NA | NA |
| Fluoranthene | 10 | 26-137 | 15 | NA | 30 | NA | NA | NA |
| Butyl Benzyl Phthalate | 10 | D-152 | 13 | NA | 25 | NA | NA | NA |
| Chrysene | 10 | 17-168 | 10 | NA | 21 | NA | NA | NA |
| Benzo(h)Fluoranthene | 10 | 24-159 | 10 | NA | 20 | NA | NA | NA |
| Dibenzo(a,h)Anthracene | 10 | D-227 | 10 | NA | 20 | NA | NA | NA |
| Benzo(g,h,i)Perylene | 10 | D-219 | 15 | NA | 30 | NA | NA | NA |
| Chlorobenzene | NS | NS | -f | NA | 104 | NA | NA | NA |

(Continued)

TABLE 2. (Cont'd) OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR SEMI-VOLATILE BASE/NEUTRAL EXTRACTABLE ORGANICS IN WATER SAMPLES - EPA METHOD 8270 - GC/MS (PK - MORRISVILLE, NC)

| Parameter | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | 3 | | 2 | |
|------------------------------|--|---|--------------------|-----------------------|--------------------|-----------------------|--------------------|-----------------------|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Audit Value (ug/L) | Reported Value (ug/L) | Audit Value (ug/L) | Reported Value (ug/L) |
| D ₅ -Microbenzene | NS | 35-114 | 50 | NR | 50 | NR | NR | 88 |
| 2-Fluorobiphenyl | NS | 21-100 | 50 | NR | 50 | NR | 79 | 72 |
| D ₁₄ -Terphenyl | NS | 33-141 | 50 | NR | 50 | NR | 85 | 76 |

^aDetection Limit as published in EPA Method 8270.

^bExpected range of recovery for spiked analytes in water matrix (Reference EPA Method 625).

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dCannot be calculated or calculation not meaningful.

^eMeasured value outside the acceptable range of recovery (underlined for emphasis).

^fNot contained in audit sample.

^gFor surrogate spikes, expected range of recovery and audit value (spiking level) taken from EPA GLP protocol.

^hMeasured value outside expected range of recovery (underlined for emphasis).

- D - Detected.
- NS - Not Specified.
- NR - Not Reported.
- NA - Not Analyzed for.
- ND - Not Detected.
- FP - False Positive; analyte reported as present, but not contained in audit sample.
- FN - False Negative; analyte contained in audit sample, but not detected.

TABLE 3. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR GC/MS ANALYSES OF SEMI-VOLATILE ACID EXTRACTABLE ORGANICS IN WATER SAMPLES - EPA METHOD 8270 - GC/MS (PK - MORRISVILLE, NC)

| Parameter | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | | 3 | | | Matrix Blank Reported Value (ug/L) |
|---|--|---|--------------------|-----------------------|----------------------------------|--------------------|-----------------------|----------------------------------|------------------------------------|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) | |
| 2-Chlorophenol | 10 | 23-134 | 30 | ND | FN ^d | -e | ND | ND | |
| 2-Nitrophenol | 10 | 29-182 | 25 | ND | FN ^d | -e | ND | 14 | |
| Phenol | 10 | 5-112 | 25 | 14 | 56 | 27 | 15 | ND | |
| 2,4-Dimethylphenol | 10 | 32-119 | 15 | ND | FN ^d | -e | ND | ND | |
| 2,4-Dichlorophenol | 10 | 39-135 | 25 | ND | FN ^d | -e | ND | ND | |
| 2,4,6-Trichlorophenol | 10 | 37-144 | 25 | ND | FN ^d | -e | ND | 12 | |
| 4-Chloro-3-methylphenol ^g | 20 | 22-147 | 23 | ND | FN ^d | -e | ND | ND | |
| 2-Methyl-4,6-dinitrophenol | 50 | 8-181 | 75 | ND | FN ^d | -e | ND | ND | |
| Pentachlorophenol | 50 | 14-176 | 38 | ND | FN ^d | -e | ND | ND | |
| 4-Nitrophenol | 50 | 8-132 | 25 | ND | FN ^d | -e | ND | 6 | |
| 2,4-Dinitrophenol | 50 | 8-191 | -e | ND | -f | -e | ND | ND | |
| Surrogate Spike Recoveries^h | | | | | | | | | |
| 2-Fluorophenol | NS | 21-100 | 50 | NR | 89 | 50 | NR | 82 | |
| d ₆ -Phenol | NS | 10-94 | 50 | NR | 87 | 50 | NR | 91 | |
| 2,4,6-Tribromophenol | NS | 10-123 | 50 | NR | 75 | 50 | NR | 81 | |

^aDetection limit as published in EPA Method 8270.

^bExpected range of percent recovery for spiked analytes in water matrix (Reference EPA Method 625).

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dValues less than 5 times the detection limit; measurements in this range are not indicative of typical performance.

^eNot contained in audit samples.

^fCannot be calculated or calculation not meaningful.

^gReported as P-Chloro-M-Cresol.

^hFor surrogate spikes expected range of recovery and audit value (spiking level) taken from EPA GLP protocol.

D - Detected; result must be greater than zero. NR - Not Reported; laboratory routinely reports only the % recovery for spikes.
 ND - Not Detected. FN - False Negative; analyte contained in audit sample, but not detected.

TABLE 4. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR POLYCHLORINATED BIPHENYLS IN WATER SAMPLES --
EPA METHOD 8080 - GC/MSD (PTK - MORRISVILLE, NC)

| Parameter | Method Detection Limit ^a (ug/L) | EPA Performance Specifications ^b (% Recovery) | 1 | | 3 | | 2 Matrix Blank Reported Value (ug/L) |
|-------------------|---|---|--------------------------|-----------------------------|--------------------------|-----------------------------|--|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Audit Value (ug/L) | Reported Value (ug/L) | |
| Arochlor No. 1260 | NS | 39-135 | 8.44 | MA | - ^c | MA | MA |
| Arochlor No. 1254 | NS | 39-135 | - ^c | MA | 10.8 | MA | MA |

^aDetection limit not specified in EPA Method 8080.

^bExpected range of recovery based on EPA interlaboratory testing.

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dCannot be calculated or calculation not meaningful.

^eNot contained in audit sample.

NS - Not Specified.
MA - Not Analyzed for.

TABLE 5. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR HEXAVALENT CHROMIUM IN WATER SAMPLES - SF-846 METHOD 7196 - Colorimetric (PK - MORRISVILLE, NC)

| Parameter | Method Detection Limit ^a (mg/L) | Expected Range of Recovery ^b (%) | 1 | | 3 | | 2 | |
|------------------|--|---|--------------------|-----------------------|--------------------|-----------------------|--------------------|-----------------------|
| | | | Audit Value (mg/L) | Reported Value (mg/L) | Audit Value (mg/L) | Reported Value (mg/L) | Audit Value (mg/L) | Reported Value (mg/L) |
| Cr ⁶⁺ | 0.2 | 80-120 | 250 | 268 | 25 | 21.4 | 86 | <0.2 |

^aLaboratory reported detection limit.

^bReported ranges of recovery specified by SSI QA Plan.

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

TABLE 6. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR METALS IN WATER SAMPLES - METHOD 6010 - ICPRIS (SFC - SACRAMENTO, CA)

| Parameter | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | | 3 | | | 2 | | |
|-----------|--|---|--------------------|-----------------------|----------------------------------|--------------------|-----------------------|----------------------------------|--------------------|-----------------------|----------------------------------|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) |
| Beryllium | 0.3 | MS | -e | ND | -f | -e | ND | -f | <1 (1) | | |
| Cadmium | 4 | 71-119 | 65 | 70 | 108 | 64 | 70 | 109 | <4 | | |
| Chromium | 7 | 84-116 | 98 | 100 | 102 | 68 | 70 | 103 | <7 | | |
| Copper | 6 | MS | -e | ND | -f | -e | NA | -f | <6 | | |
| Cobalt | 7 | MS | -e | NA | -f | -e | ND | -f | NA | | |
| Nickel | 15 | MS | -e | ND | -f | -e | ND | -f | <15 | | |
| Zinc | 2 | MS | -e | ND | -f | -e | ND | -f | <2 | | |

^aDetection limits as published in EPA Method 200.7.
^bExpected range of recovery, based on interlaboratory testing.
^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.
^dNumbers in parentheses are laboratory detection limits, reported if significantly different from the expected method detection limit.
^eNot contained in audit sample.
^fCannot be calculated or calculation not meaningful.
 NA - Not Analyzed for.
 ND - Not Detected.

TABLE 7. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR METALS IN WATER SAMPLES - AA (SFC - SACRAMENTO, CA)

| Parameter | 1 | | | 3 | | | Matrix Blank Reported Value ^d (ug/L) |
|-----------|--|---|------------------------|-----------------------|----------------------------------|------------------------|---|
| | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | Certified Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) | Certified Value (ug/L) | |
| Arsenic | 1 | 77-122 | 46 | 50 | 109 | 40 | 40 (4) |
| Lead | 1 | 66-141 | 53 | 60 | 113 | 34 | 40 (4) |
| Selenium | 2 | 60-124 | 28 | 30 | 107 | 28 | 30 (4) |

^aDetection limit as published in Methods for Chemical Analysis of Water and Wastes.

^bExpected range of recovery based on interlaboratory testing.

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dNumbers in parentheses are laboratory detection limits, reported if significantly different from the expected method detection limit.



TABLE 8. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR METALS IN A FILTER SAMPLE - METHOD 6010 - ICPES (SPC - SACRAMENTO, CA)

| Parameter | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | |
|-----------|--|---|--------------------|-----------------------|----------------------------------|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) |
| Beryllium | 0.3 | NS | 7.5 | 20 | 267 |
| Cadmium | 4 | 71-119 | 2230 | 3600 | 161 ✓ |
| Chromium | 7 | 84-116 | 2070 | 4200 | 202 |
| Copper | 6 | NS | - ^d | 70 | FP |
| Nickel | 15 | NS | 5240 | 9100 | 174 |
| Zinc | 2 | NS | - ^d | 180 | FP |

^aDetection limits as published in EPA Method 200.7.

^bExpected range of recovery, based on interlaboratory testing.

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dNot contained in audit sample.

NS - Not Specified.

FP - False Positive; analyte reported as present, but not contained in audit sample.

NOTE: Audit values reflect a 100 mL digestate volume reported by SPC.



TABLE 9. OCTOBER 1987 PERFORMANCE AUDIT RESULTS FOR METALS IN A FILTER SAMPLE - AA ANALYSES (SPC - SACRAMENTO, CA)

| Parameter | Method Detection Limit ^a (ug/L) | Expected Range of Recovery ^b (%) | 1 | | |
|-----------|---|--|--------------------------|-----------------------------|--|
| | | | Audit Value (ug/L) | Reported Value (ug/L) | Sample Recovery ^c (%) |
| Arsenic | 1 | 77-122 | 430 | 1100 | 256 ^d |
| Lead | 1 | 66-141 | 4000 | 11000 | 275 ^d |
| Selenium | 2 | 60-124 | - ^e | ND | - ^f |

^aFrom EPA Methods for Chemical Analysis of Water and Wastes, June, 1982.

^bExpected range of recovery based on interlaboratory testing.

^cSample Recovery (%) = $\frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

^dMeasured value outside the acceptable range of recovery.

^eNot contained in audit sample.

^fCannot be calculated or calculation not meaningful.

ND - Not Detected.

NOTE: Audit values reflect a 100 mL digestate volume reported by SPC.

A.4 RESULTS OF SLUDGE ANALYSES, PERCENT SOLIDS AND PERCENT VOLATILE SOLIDS;
OCTOBER 15, 1987

MICHAEL TRAFICANTE
MAYOR



A. JOSEPH MATTERA
SUPERINTENDENT
RAYMOND AZAR
DIRECTOR

**DEPARTMENT OF PUBLIC WORKS
WATER CONTROL FACILITIES**
140 PETTACONSETT AVENUE
CRANSTON, RHODE ISLAND 02920

October 15, 1987

Mr. Michael Palazzolo
Senior Engineer/Group Leader
Radian Corporation
Progress Center
3200 E.Chapel Hill Road/Nelson Hwy.
P. O. Box 13000
Research Triangle Park, NC 27709

Dear Sir:

Enclosed is a copy of the laboratory results for your submitted samples.

If you have any questions or if I can be of any further help, please feel free to contact me.

Sincerely,

Paul E. Fitzgibbons
Chemist

PF/jl

cc:A.Joseph Mattera/W.C.F.
enclosure

| Date | Sample | o/o TS | o/o VS |
|-------|-------------------|--------|--------|
| 9/30 | CRA-0930-SF-MC-01 | 28.0 | 53.6 |
| 9/30 | CRA-9 | 34.0 | 51.5 |
| 10/1 | CRA-292 | 29.6 | 51.0 |
| 10/2 | CRA-296 | 29.9 | 53.2 |
| 10/3 | CRA-301 | 29.5 | 57.3 |
| 10/4 | CRA-327 | 27.9 | 59.3 |
| 10/5 | CRA-334 | 25.9 | 52.5 |
| 10/6 | CRA-344 | 29.9 | 56.9 |
| 10/6 | CRA-352 | 29.6 | 55.1 |
| 10/8 | CRA-354 | 28.8 | 58.7 |
| 10/8 | CRA-357 | 28.1 | 56.6 |
| 10/8 | CRA-369 | 26.9 | 57.6 |
| 10/9 | CRA-445 | 28.5 | 58.9 |
| 10/9 | CRA-446 | 29.4 | 57.8 |
| 10/9 | CRA-447 | 29.5 | 56.9 |
| 10/10 | CRA-448 | 29.5 | 57.6 |
| 10/10 | CRA-450 | 30.9 | 57.9 |



A.5 RESULTS OF SLUDGE HIGHER HEATING VALUE AND ULTIMATE ANALYSES,
NOVEMBER 6, 1987



SINCE 1908

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (312) 953-9300

Member of the SGS Group (Société Générale de Surveillance)

PLEASE ADDRESS ALL CORRESPONDENCE TO:
18130 VAN DRUNEN RD., P.O. BOX 127
SOUTH HOLLAND, IL 60473
TELEPHONE: (312) 264-1173
TELEX: 285950 COMTECO SH UR

RADIAN CORPORATION
3200 Progress Center/Hwy 54
P.O. Box 13000
Research Triangle Park, NC 27709

November 6, 1987

Sample identification
by Radian Corp.

ATTN: J.F. McGaughey

Sample I.D.: See Below

Kind of sample reported to us Sludge

Sample taken at -----

Sample taken by Radian Corp.

Date sampled -----

Date received 11/2/87

P.O. No. 60190

Analysis report no. 71-47083, 47084, 47086, 47088-47092

Radian Corporation
Identification

Btu/lb., As Received

| | |
|-------|------|
| CRA-7 | 1764 |
| 243 | 2050 |
| 245 | 1827 |
| 247 | 1517 |
| 248 | 2041 |
| 249 | 1919 |
| 250 | 1898 |
| 444 | 1957 |

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

A-72

Manager, South Holland Laboratory



Charter Member

Original Copy Watermarked
For Your Protection

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

F-484

DWC/ds

COMMERCIAL TESTING & ENGINEERING CO.

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LLOYD W. TAYLOR III
MANAGER
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PLEASE ADDRESS ALL CORRESPONDENCE TO:
16130 VAN DRUNEN RD., P.O. BOX 127
SOUTH HOLLAND, IL 60473
OFFICE TEL. (312) 264-1173
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▶ RADIANT CORPORATION
3200 Progress Center/Hwy 54
P.O. Box 13000
Research Triangle Park, NC 27709

ATTN: J.F. McGaughey

November 6, 1987

Sample identification
by Radian Corp.

Kind of sample reported to us Sludge Sample I.D.: 246
Sample taken at -----
Sample taken by Radian Corp.
Date sampled -----
Date received 11/2/87 P.O. No. 60190

Analysis report no. 71-47087

PROXIMATE ANALYSIS

| | <u>As Received</u> | <u>Dry Basis</u> |
|----------------|--------------------|------------------|
| % Moisture | 71.77 | xxxxx |
| % Ash | 9.11 | 32.26 |
| % Volatile | 17.70 | 62.70 |
| % Fixed Carbon | 1.42 | 5.04 |
| | <u>100.00</u> | <u>100.00</u> |
| Btu/lb. | 1887 | 6686 |
| % Sulfur | 0.16 | 0.56 |

ULTIMATE ANALYSIS

| | <u>As Received</u> | <u>Dry Basis</u> |
|-----------------|--------------------|------------------|
| % Moisture | 71.77 | xxxxx |
| % Carbon | 10.19 | 36.09 |
| % Hydrogen | 1.46 | 5.17 |
| % Nitrogen | 0.93 | 3.29 |
| % Chlorine | ---- | ---- |
| % Sulfur | 0.16 | 0.56 |
| % Ash | 9.11 | 32.26 |
| % Oxygen (diff) | 6.38 | 22.63 |
| | <u>100.00</u> | <u>100.00</u> |

SULFUR FORMS

| | <u>As Received</u> | <u>Dry Basis</u> |
|-------------------------|--------------------|------------------|
| % Pyritic Sulfur | ---- | ---- |
| % Sulfate Sulfur | ---- | ---- |
| % Organic Sulfur (Diff) | ---- | ---- |
| % Total Sulfur | ---- | ---- |

FUSION TEMPERATURE OF ASH

| | <u>Reducing</u> | <u>Oxidizing</u> |
|-----------------------|-----------------|------------------|
| Initial Deformation | ---- °F | ---- °F |
| Softening (H = W) | ---- °F | ---- °F |
| Softening (H = 1/2 W) | ---- °F | ---- °F |
| Fluid | ---- °F | ---- °F |

HARDGROVE GRINDABILITY INDEX = ---- at ---- % Moisture

% EQUILIBRIUM MOISTURE = ----

FREE SWELLING INDEX = ----

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

David W Cox

A-73 David W. Cox, Manager, South Holland Laboratory



Charter Member

Original Copy Watermarked
For Your Protection

DWC/ds

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

A.6 SUMMARY OF PROCESS OPERATING AND SAMPLING PARAMETERS FOR THE METAL
EMISSION TEST RUNS

SUMMARY OF PROCESS OPERATING AND SAMPLING PARAMETERS USED
 TO OBTAIN THE RAW ANALYTICAL METALS DATA FROM THE CONTROL
 DEVICE OUTLET SAMPLING LOCATION

 AVERAGE PARAMETER VALUE FOR ENTIRE RUN

| PARAMETER | RUN 01 | RUN 02 | RUN 03 | RUN 04 | RUN 05 | RUN 06 | RUN 07 | RUN 08 | RUN 09 | RUN 10 | RUN 11 | AVERAGE |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| ----- FLUE GAS SAMPLING PARAMETERS ----- | | | | | | | | | | | | |
| FLUE GAS SAMPLED (scfm) | 21.30 | 21.04 | 21.14 | 19.98 | 21.15 | 21.33 | 21.40 | 21.48 | 21.54 | 21.24 | 21.51 | 21.28 |
| FLUE GAS FLOW RATE (scfm) | 178.69 | 185.83 | 163.11 | 151.37 | 157.69 | 172.44 | 178.28 | 183.87 | 187.93 | 167.26 | 185.54 | |
| TOTAL PARTICULATE CAPTURE (mg) | 195.0 | 90.4 | 83.9 | 83.8 | 262.4 | 142.3 | 131.3 | 190.8 | 156.2 | 122.4 | 191.1 | |
| OXYGEN (%, dry basis) | 14.4 | 13.1 | 14.1 | 14.1 | 11.3 | 11.3 | 14.5 | 15.1 | 15.1 | 15.1 | 14.5 | |
| CARBON DIOXIDE (%, dry basis) | 4.4 | 5.7 | 4.3 | 4.3 | 7.0 | 7.0 | 4.1 | 3.6 | 3.6 | 3.6 | 4.2 | |
| ----- SLUDGE FEED PARAMETERS ----- | | | | | | | | | | | | |
| SLUDGE FEED RATE (tons/hr) | 2.26 | 2.08 | 2.25 | 2.56 | 2.22 | 2.07 | 2.12 | 2.05 | 2.04 | 2.11 | 2.13 | |
| SLUDGE FEED RATE (metric ton/hr) | 2.05 | 1.89 | 2.04 | 2.32 | 2.01 | 1.88 | 1.92 | 1.86 | 1.85 | 1.91 | 1.93 | |
| SLUDGE FEED % MOISTURE | 72.0 | 66.0 | 70.4 | 70.1 | 70.4 | 71.2 | 71.9 | 71.5 | 70.6 | 70.5 | 70.5 | |
| SLUDGE FEED % VOLATILES (wet basis) | 15.0 | 17.5 | 15.1 | 15.9 | 16.3 | 16.9 | 15.9 | 16.8 | 17.0 | 16.8 | 17.0 | |
| DRY SLUDGE FEED RATE (metric ton/hr) | 0.574 | 0.542 | 0.504 | 0.594 | 0.596 | 0.541 | 0.540 | 0.530 | 0.544 | 0.565 | 0.570 | |
| SLUDGE COMBUST- IBLES FEED RATE (metric ton/hr) | 0.308 | 0.283 | 0.306 | 0.348 | 0.302 | 0.282 | 0.288 | 0.279 | 0.278 | 0.287 | 0.290 | |

| | | | | | | | | | | | |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| SCOURBER WATER INLET FLOW, gpa | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 | 196.0 |
| SCOURBER WATER INLET FLOW (liters/min) | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 | 741.9 |
| SCOURBER WATER OUTLET FLOW, gpm | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 | 208.0 |
| SCOURBER WATER OUTLET FLOW (liters/min) | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 | 787.3 |
| BOTTOM ASH | | | | | | | | | | | |
| BOTTOM ASH FLOW RATE (metric ton/hr) | 0.184 | 0.169 | 0.183 | 0.208 | 0.181 | 0.168 | 0.173 | 0.167 | 0.166 | 0.172 | 0.173 |

A.7 PARTICLE SIZE DISTRIBUTION RESULTS, INLET AND OUTLET

PARTICLE SIZE DISTRIBUTION OF UNCONTROLLED AND CONTROLLED FLUE GASES;
CRANSTON SEWAGE SLUDGE INCINERATOR

| Sample ID | Mass Concentration gr/dscf | Sampling Location | 50% Cut Point ^a Mass Basis | Mass Fraction, ^b < 2.0 μ m |
|-----------|-------------------------------|-------------------|--|--|
| U | 0.012 | Outlet | < 0.42 μ m | 88% |
| Z | 0.035 | Outlet | < 0.54 μ m | 87% |
| X | 0.039 | Outlet | 0.80 μ m | 54% |
| D | 1.000 | Inlet | 7.0 μ m | 24% |
| Y | 0.604 | Inlet | > 13.3 μ m | 11% |

^aThe 50% cut point represents the particle diameter that marks the point where half of the particulate mass in the flue gas stream is smaller than the stated size and half is larger.

^bThe < 2 μ m denotes the percentage of particulate mass which is smaller than 2 μ m in diameter.

APPENDIX B

EMISSION FACTOR DEVELOPMENT

APPENDIX B
EMISSION FACTOR DEVELOPMENT

| <u>Section</u> | | <u>Page</u> |
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| | B.3.2 Average Case Esimtates | B-5 |
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| B.4 | Supporting Data | B-11 |

APPENDIX B EMISSION FACTOR DEVELOPMENT

B.1 INTRODUCTION

Emission factor estimates for each of the two Rhode Island incinerators are developed for purposes of conducting emission modeling. These emission factors are key inputs into the dispersion modeling calculations. Tests recently performed at the Cranston facility are the basis for emission factors for that incinerator. No plant specific emission factors were available for Fields Point. As a means of developing reasonable emission estimates based on the information known about the plant, Radian developed a model. The model utilizes site specific information to the extent that such data are available. In the absence of site specific data, the model relies on data reported in the literature for similar incineration facilities.

In general, this approach utilizes existing data to predict uncontrolled emission rates for each metal. Existing data are also used to predict how these uncontrolled emissions are distributed as a function of mean particle diameter. From this information controlled emission rates are determined on the basis of known relationships between control device design, operating conditions and removal efficiency.

B.2 DESCRIPTION OF EMISSION FACTOR MODEL

Several variables are known to affect emissions from sludge incinerators. Among these factors are furnace design, operating conditions, sludge characteristics, control device design and operation. As an attempt to address as many of these factors as possible. The Radian model considers five variables. When possible these variables were defined using data specific to the Fields Point facility, where such data were unavailable, variables were defined using existing data combined with engineering judgment. The key variables are: (1) sludge feed rate, (2) average metal content of incoming sludge, (3) proportion of the incoming sludge metal

content released in the uncontrolled offgases, (4) percent of total uncontrolled metal emission in each size fraction, and (5) particulate removal efficiency of the scrubber for each particle size.

Figure B-1 contains an example calculation illustrating the emission factor development approach. As shown in the example, Elements "A" and "B" of the equation are defined based on the sludge feed rate to the incinerator and the average sludge metal concentration. Sludge feed rate (Element A) for Fields Point is defined as the incinerator design capacity and the sludge metal concentration (Element B) is based on the average sludge metal concentration supplied by Fields Point for the period between January 1985 and September 1986. Element "C" of the equation shown in Figure B-1 is derived from the existing uncontrolled emissions data for those tests where sludge metal concentrations were monitored (literature sources), and Element "D" is based on those test runs where uncontrolled metal emissions were fractionated by particle size (literature sources). The percent of sludge metal content released in the incinerator offgases (Element C) and the percent of the uncontrolled metal emission in each particle size fraction (Element D) is judged to be very dependent upon incinerator operating conditions. Therefore, these values were derived based on existing emissions data, incinerator operating records and engineering judgement. Element "E" is estimated based on control device design data and average scrubber pressure drop recorded at Fields Point during previous operating records. An example, showing the relationship between scrubber efficiency, particle size, and pressure drop is included as Figure B-2.

Emission factor estimates for arsenic, beryllium, and selenium cannot be made for Fields Point using the approach described in Figure B-1 since these metals were not included in the Fields Point sludge monitoring program.

B.3 EMISSION FACTOR CALCULATIONS

The Radian model was used to calculate four emission factor estimates for each of the target metals. These include a "lower bound" estimate, an "average," an "average based on plant specific scrubber operation records," and an "upper bound" estimate. Modeling results presented in this document are based on the emission estimates derived from the average case using

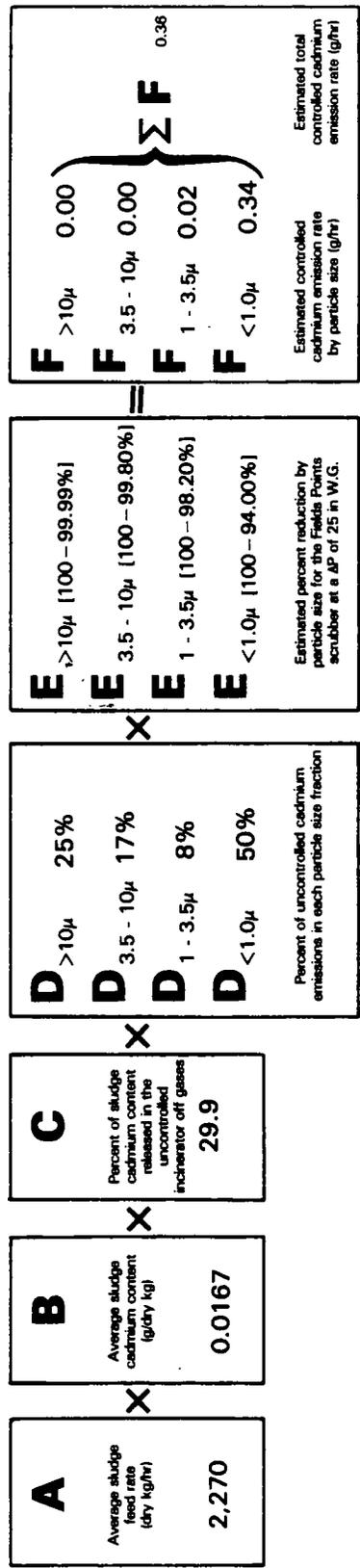


Figure B-1. Example Calculation Showing Emission Factor Development Approach

COLLECTION EFFICIENCY VS. PARTICLE SIZE

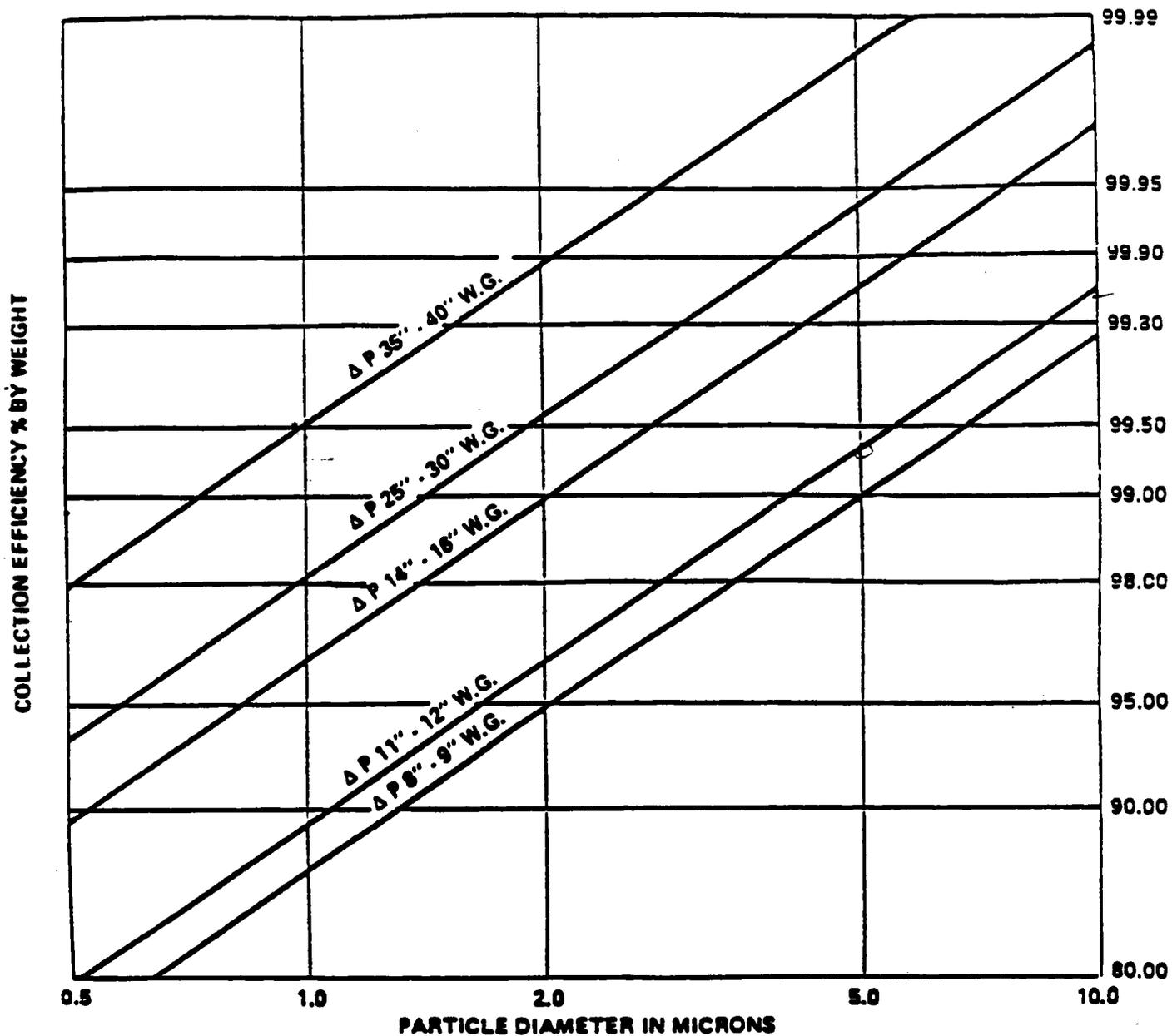


Figure B-2. Example, showing the relationship between scrubber efficiency, particle size, and pressure drop.

plant specific scrubber operation records (B.3.3). Table B-1 contains this range of emission factor estimates for the metals targeted in this study. Table B-2 contains the inputs and results for the emission factor calculations. The following subsections briefly explain each estimate.

B.3.1 Lower Bound Estimate

This emission estimate is derived to bound the range on the low end that is, the lower bound estimate describes emissions under the absolute best case or lowest emitting scenario. This estimate is derived by setting the metal content of incoming sludge (Element B in the model) at the lowest level of any of the reported samples. Next, the percent of sludge metal content released into the uncontrolled incinerator offgases is assumed to be the smallest value reported in all literature sources.

Size distribution of metals in the uncontrolled offgases is assumed to be distributed primarily in the larger particle sizes, again based on the "best case" of all literature sources. Scrubber operation is assumed to remain constant at best case conditions of 40 in. pressure drop, which results in the largest emission reduction.

B.3.2 Average Case Estimates

These emission estimates represent results that are derived using average values for each of the model variables. Under this scenario, the scrubber is assumed to be operated continuously at a pressure drop of 25 inches of water.

B.3.3 Average Case Based On Actual Scrubber Operation Records

These emission estimates represents factors that are derived using average values for each of the model Elements A, B, C, and D. Actual scrubber operation records are used to estimate a time weighted scrubber system pressure differential. Available operational records from July 1982 were reviewed and the data were reduced to determined the amount of time the scrubber was operated in each of four pressure drop ranges. Table B-3 shows a summary of these data.

TABLE B-1. EMISSION RATE ESTIMATES FOR FIELDS POINT (g/hr)

| Metal | Lower Bound Estimate | Average Case Estimate | Average Case Based on Actual Scrubber Records | Upper Bound Estimate |
|-----------|----------------------|-----------------------|---|----------------------|
| Arsenic | NA | NA | NA | NA |
| Beryllium | NA | NA | NA | NA |
| Cadmium | 0.025 | 0.7 | 1.9 | 11.8 |
| Copper | 0.109 | 24.8 | 139.9 | 1574 |
| Chromium | 0.005 | 4.4 | 22.4 | 271.6 |
| Lead | 0.127 | 7.6 | 24.8 | 275.9 |
| Nickel | 0.002 | 4.3 | 21.9 | 268.3 |
| Selenium | NA | NA | NA | NA |
| Zinc | 0.084 | 44.3 | 201.3 | 1892 |

NA = Not available since Fields Point and sludge data analysis do not include these metals.

TABLE B-2. MODEL INPUTS FOR EMISSION FACTOR CALCULATIONS

(AVERAGE, UPPER BOUND, AND LOWER BOUND VALUES FOR ELEMENTS A THROUGH C)

| Sludge Metal | Element "A" | | Element "B" | | Element "C" | | |
|--------------|----------------------------------|-------------------------------------|---|---|--|--|--|
| | Average Sludge Feed Rate (kg/hr) | Average Sludge Metal Content (g/kg) | Upper Bound Sludge Metal Content (g/kg) | Lower Bound Sludge Metal Content (g/kg) | Average Percent of Sludge Metal Content in Uncontrolled Offgas | Upper Bound Percent of Sludge Metal Content in Uncontrolled Offgas | Lower Bound Percent of Sludge Metal Content in Uncontrolled Offgas |
| Cd | 2270 | 0.0167 | 0.0253 | 0.0047 | 44.8 | 76.2 | 16.9 |
| Cr | 2270 | 0.5410 | 1.2850 | 0.2200 | 12.21 | 57.0 | 0.8 |
| Cu | 2270 | 3.4600 | 8.1190 | 1.5560 | 14.4 | 87.0 | 0.8 |
| Pb | 2270 | 0.3780 | 0.6120 | 0.2220 | 6.9 | 41.3 | 4.0 |
| Ni | 2270 | 0.5320 | 1.3120 | 0.2710 | 12.1 | 58.0 | 0.2 |
| Zn | 2270 | 3.7770 | 8.1300 | 1.7970 | 8.5 | 38.2 | 0.9 |

TABLE B-2. (Continued)

(AVERAGE, UPPER BOUND, AND LOWER BOUND VALUES FOR ELEMENT-D)

| Sludge Metal | Average Metal PM Distribution (%) | | Upper Bound Metal PM Distribution (%) | | Lower Bound Metal PM Distribution (%) | | | | | | | |
|-----------------|-----------------------------------|----------|---------------------------------------|----------|---------------------------------------|----------|---|----|----|----|----|----|
| | > 10 u | 3.5-10 u | > 10 u | 3.5-10 u | > 10 u | 3.5-10 u | | | | | | |
| Cd | 25 | 27 | 8 | 50 | 1 | 1 | 1 | 97 | 29 | 44 | 11 | 16 |
| Cr | 50 | 19 | 7 | 24 | 35 | 18 | 9 | 38 | 76 | 19 | 4 | 1 |
| Cu | 44 | 29 | 7 | 20 | 54 | 1 | 1 | 44 | 44 | 46 | 3 | 7 |
| Pb | 29 | 19 | 8 | 44 | 5 | 0 | 1 | 94 | 66 | 12 | 5 | 17 |
| Ni | 46 | 23 | 7 | 24 | 36 | 19 | 8 | 37 | 55 | 38 | 6 | 1 |
| Zn | 42 | 24 | 7 | 27 | 24 | 26 | 7 | 43 | 73 | 19 | 4 | 4 |

TABLE B-2. (Continued)

(AVERAGE, UPPER BOUND, AND LOWER BOUND VALUES FOR ELEMENT E)

| Sludge Metal | Average Penetration by Size Distribution @ P = 25 in. W.G. | | | Upper Bound Penetration by Size Distribution @ P = 12 in. W.G. | | | Lower Bound Penetration by Size Distribution @ P = 40 in. W.G. | | | | | |
|-----------------|---|----------|---------|--|--------|----------|--|-------|---------|----------|---------|-------|
| | > 10 u | 3.5-10 u | 1-3.5 u | 1.0 u | > 10 u | 3.5-10 u | 1-3.5 u | 1.0 u | > 10 u | 3.5-10 u | 1-3.5 u | 1.0 u |
| Cd | 0.00015 | 0.0018 | 0.018 | 0.06 | 0.0015 | 0.016 | 0.11 | 0.21 | 0.00001 | 0.0004 | 0.0005 | 0.02 |
| Cr | 0.00015 | 0.0018 | 0.018 | 0.06 | 0.0015 | 0.016 | 0.11 | 0.21 | 0.00001 | 0.0004 | 0.0005 | 0.02 |
| Cu | 0.00015 | 0.0018 | 0.018 | 0.06 | 0.0015 | 0.016 | 0.11 | 0.21 | 0.00001 | 0.0004 | 0.0005 | 0.02 |
| Pb | 0.00015 | 0.0018 | 0.018 | 0.06 | 0.0015 | 0.016 | 0.11 | 0.21 | 0.00001 | 0.0004 | 0.0005 | 0.02 |
| Ni | 0.00015 | 0.0018 | 0.018 | 0.06 | 0.0015 | 0.016 | 0.11 | 0.21 | 0.00001 | 0.0004 | 0.0005 | 0.02 |
| Zn | 0.00015 | 0.0018 | 0.018 | 0.06 | 0.0015 | 0.016 | 0.11 | 0.21 | 0.00001 | 0.0004 | 0.0005 | 0.02 |

TABLE B-3. FIELD'S POINT SCRUBBER SYSTEM OPERATING SUMMARY: HOURS PER DAY THE SCRUBBER SYSTEM WAS OPERATED IN EACH OF FOUR PRESSURE DROP RANGES, JULY 1982

| Date | ΔP in. H ₂ O Gauge | | | |
|---|---------------------------------------|--------|-----------|-----------|
| | 0 - 5 | 5 - 19 | 19.1 - 31 | 31.1 - 49 |
| 7-2-82 | | 1 | 11 | 3 |
| 7-3-82 | | 3 | 17 | 4 |
| 7-4-82 | | | 13 | 6 |
| 7-5-82 | 12 | | 6 | 6 |
| 7-9-82 | | | 1 | 1 |
| 7-10-82 | 3 | 3 | 11 | 6 |
| 7-13-82 | 2 | 2 | 14 | 6 |
| 7-15-82 | 1 | | 12 | 5 |
| 7-16-82 | | | 4 | 20 |
| 7-17-82 | 3 | 4 | 11 | 3 |
| 7-19-82 | 3 | 2 | 11 | 4 |
| 7-20-82 | | 9 | 14 | |
| 7-21-82 | 1 | 15 | 4 | 4 |
| 7-22-82 | | 3 | 8 | 9 |
| 7-23-82 | | 1 | 22 | 1 |
| 7-24-82 | | | 24 | |
| 7-25-82 | | | 13 | 1 |
| 7-26-82 | | | 24 | |
| 7-27-82 | 1 | | 15 | 2 |
| 7-28-82 | | | 21 | 3 |
| 7-29-82 | | | 9 | 4 |
| 7-30-82 | | 1 | 8 | 2 |
| 7-31-82 | | | 6 | |
| | 26 hrs | 44 hrs | 279 hrs | 90 hrs |
| Percent of Operating Time in Each Range | 5.9% | 10.0% | 63.6% | 20.5% |

B.3.4 Upper Bound Estimate

This emission estimate is derived to bound the emission factor range on the upper end. That is, this estimate describes emissions under the worst case or highest emitting scenario. Directly the opposite of the lower bound estimate. This estimate is derived by assuming the highest values for each of the model inputs. Scrubber operating conditions are assumed to be constant at a pressure drop of 12 inches of water.

B.4 SUPPORTING DATA

Data used to formulate the Radian model are presented in summary form in this section. Table B-4 contains monthly averages of trace metal concentrations measured in Fields Point sludge cake between January 1988 and November 1986.

Table B-5 contains the metal content of the Fields Point sludge as reported between April and November 1986. These data were used to develop the upper, lower and average values for Element B of the model.

Table B-6 contains a summary of metal concentrations in uncontrolled incinerator offgases expressed as a percentage of the metal feed rate. These data were used to develop the upper, lower and average values for Element C of the model.

Tables B-7 through B-14 contain summaries of metal content in uncontrolled incinerator offgases by particle size. These data were used to develop upper, lower and average values for Element D of the model.

Table B-15 contains a summary of operation parameters at the Fields Point plant during the most recent period of continuous operation, July 1982.

TABLE B-4. VARIATION IN TRACE METAL CONCENTRATIONS MEASURED IN FIELDS POINT SLUDGE CAKE BETWEEN APRIL AND NOVEMBER 1986

| Sample Collection Date | PPM (WT.) IN DRY SLUDGE | | | | | | | | | | |
|---------------------------|-------------------------|-------|-------|------------------|-----|-----|-------|------|-------|--|--|
| | Cd | Cu | Cr | Cr ⁺⁶ | Pb | Hg | Ni | Ag | Zn | | |
| 04/09/86 | 9.8 | 1,680 | --- | 526.0 | 262 | --- | 370 | 7.8 | 1,797 | | |
| 04/12/86 | 15.6 | 1,556 | --- | 642.0 | 295 | --- | 337 | 7.5 | 2,528 | | |
| 04/16/86 | 25.3 | 3,921 | --- | 950.0 | 392 | --- | 506 | 6.8 | 3,637 | | |
| 05/09/86 | 17.7 | 1,807 | 623 | 158.1 | 269 | 1.6 | 369 | 91.0 | 3,063 | | |
| 05/16/86 | 14.1 | 1,884 | 699 | 112.3 | 222 | 2.4 | 271 | 71.4 | 2,597 | | |
| 06/11/86 | 12.8 | 1,599 | 220 | 43.0 | 302 | --- | 438 | 37.0 | 2,345 | | |
| 06/27/86 | 23.3 | 5,211 | 509 | 11.0 | 402 | --- | 648 | 93.9 | 4,128 | | |
| 07/22/86 | 21.6 | 2,605 | 448 | 46.8 | 572 | 1.1 | 540 | 95.0 | 4,203 | | |
| 07/29/86 | 20.4 | 3,209 | 472 | 20.6 | 612 | 1.0 | 441 | 79.0 | 3,491 | | |
| 08/20/86 | 22.8 | 3,416 | 370 | 168.0 | 472 | 0.7 | 462 | 68.1 | 3,136 | | |
| 08/29/86 | 21.2 | 5,404 | 766 | 349.0 | 397 | 1.8 | 602 | 80.3 | 4,273 | | |
| 09/03/86 | 4.7 | 4,689 | 608 | 137.0 | 393 | 1.1 | 776 | 97.2 | 5,446 | | |
| 09/10/86 | 6.1 | 8,119 | 1,285 | 151.0 | 462 | 1.2 | 1,312 | 91.2 | 8,130 | | |
| 09/24/86 | 22.4 | 3,251 | 346 | 193.0 | 260 | 1.6 | 593 | 74.7 | 5,263 | | |
| 11/29/86 | 12.2 | 3,544 | 150 | 71.1 | 350 | 1.0 | 317 | 43.3 | 2,618 | | |
| <hr/> | | | | | | | | | | | |
| Average | 16.7 | 3,460 | 541 | 238.6 | 378 | 1.4 | 532 | 63.0 | 3,777 | | |
| Standard Deviation | 6.5 | 1,824 | 298 | 269.1 | 116 | 0.5 | 256 | 33.7 | 1,599 | | |
| High | 25.3 | 8,119 | 1,285 | 950.0 | 612 | 2.4 | 1,312 | 97.2 | 8,130 | | |
| Low | 4.7 | 1,556 | 220 | 11.0 | 222 | 0.7 | 271 | 7.5 | 1,797 | | |

TABLE B-5. MONTHLY AVERAGES OF TRACE METAL CONCENTRATIONS MEASURED IN FIELDS POINT SLUDGE CAKE
PPM (Wt) IN DRY SLUDGE

| Month | Samples | Cd | Cu | Cr | Cr ⁺⁶ | Pb | Hg | Ni | Ag | Zn |
|---------------|---------|------|---------|-------|------------------|-------|-----|-------|------|---------|
| January '85 | 3 | 10.0 | 700.0 | 0.5 | --- | 374.8 | 3.3 | 506.7 | 28.1 | 2,491.9 |
| February '85 | 4 | 15.5 | 3,178.6 | 908.2 | --- | 440.0 | 1.8 | 505.9 | 21.8 | 3,559.1 |
| March '85 | 6 | 12.4 | 2,191.4 | 25.2 | --- | 374.8 | 1.9 | 418.6 | 36.7 | 3,030.0 |
| April '85 | 8 | 13.0 | 1,760.5 | 1.0 | --- | 381.0 | 2.5 | 541.5 | 26.0 | 2,823.0 |
| May '85 | 5 | 22.3 | 1,916.4 | 5.5 | --- | 440.5 | 4.5 | 517.3 | 24.5 | 3,833.6 |
| June '85 | 8 | 17.6 | 2,071.9 | 3.3 | --- | 510.5 | 4.3 | 644.3 | 32.9 | 4,987.1 |
| July '85 | 4 | 16.7 | 2,471.1 | 3.9 | --- | 488.3 | 3.3 | 428.9 | 41.7 | 4,333.3 |
| August '85 | 5 | 11.1 | 1,689.3 | 1.8 | --- | 438.2 | 1.8 | 365.7 | 17.5 | 3,192.1 |
| April '86 | 3 | 16.5 | 2,157.0 | --- | 680.0 | 293.0 | --- | 382.0 | 6.9 | 2,571.0 |
| May '86 | 2 | 16.0 | 1,846.0 | 661.0 | 135.0 | 246.0 | 2.0 | 320.0 | 81.0 | 2,830.0 |
| June '86 | 2 | 18.1 | 3,405.0 | 365.0 | 27.0 | 352.0 | 1.0 | 543.0 | 65.6 | 3,237.0 |
| July '86 | 2 | 21.0 | 2,907.0 | 460.0 | 33.7 | 592.0 | 1.0 | 491.0 | 87.0 | 3,847.0 |
| August '86 | 2 | 22.0 | 4,410.0 | 568.0 | 259.0 | 435.0 | 1.2 | 532.0 | 74.2 | 3,705.0 |
| September '86 | 3 | 11.1 | 5,353.0 | 746.0 | 160.0 | 372.0 | 1.3 | 894.0 | 87.7 | 6,280.0 |
| November '86 | 1 | 12.2 | 3,544.0 | 150.0 | 71.1 | 350.0 | 1.0 | 317.0 | 43.3 | 2,618.0 |
| ----- | | | | | | | | | | |
| Average | | 15.7 | 2,640.0 | 278.5 | 195.1 | 405.9 | 2.2 | 473.7 | 45.0 | 3,549.9 |
| High | | 22.3 | 5,353.0 | 908.2 | 680.0 | 592.0 | 4.5 | 894.0 | 87.7 | 6,280.0 |
| Low | | 10.0 | 700.0 | 0.5 | 27.0 | 246.0 | 1.0 | 317.0 | 6.9 | 2491.9 |
| ----- | | | | | | | | | | |
| 1986 Average | | 16.7 | 3,374.6 | 491.7 | 195.1 | 377.1 | 1.3 | 497.0 | 63.7 | 3,584.0 |
| High | | 22.1 | 5,353.0 | 746.0 | 680.0 | 592.0 | 2.0 | 894.0 | 87.7 | 6,280.0 |
| Low | | 12.2 | 1,846.0 | 150.0 | 27.0 | 246.0 | 1.0 | 382.0 | 6.9 | 2,571.0 |

TABLE B-6. PERCENT OF INCOMING SLUDGE FEED METAL MEASURED IN UNCONTROLLED INCINERATOR OFFGASES (%)

| Name/Location | Reference | As | Be | Cd | Cr | Cu | Pb | Ni | Se | Zn |
|--------------------|-----------|-----|----|-------|-------|------|-------|-------|------------------|-------|
| MERL A | 24 | -- | -- | 49.7 | 9.7 | 9.2 | 11.1 | 14.2 | -- | 11.2 |
| MERL C | 24 | -- | -- | 52.2 | 4.4 | 7.8 | 6.3 | 3.3 | -- | 3.6 |
| MERL D | 24 | -- | -- | 100.0 | 57.0 | 87.0 | 100.0 | 58.0 | -- | 100.0 |
| MERL E | 24 | -- | -- | 19.8 | 0.7 | 0.2 | 6.8 | 0.2 | -- | 0.7 |
| MERL H | 24 | -- | -- | 76.2 | 13.1 | 5.7 | 41.3 | 7.1 | -- | 38.2 |
| MERL F | 24 | -- | -- | 66.9 | 0.8 | 1.7 | 6.2 | 0.6 | -- | 1.8 |
| MERL K | 24 | -- | -- | 100.0 | 100.0 | 90.4 | 100.0 | 100.0 | -- | 100.0 |
| MERL A | 30 | 2.8 | -- | 31.8 | 3.0 | 2.6 | 6.8 | 3.1 | BDL ^a | 2.8 |
| MERL B | 30 | 5.9 | -- | 16.9 | 9.0 | 0.8 | 4.0 | 10.1 | 3.3 | 0.9 |
| Average | | 4.4 | -- | 57.1 | 22.0 | 22.8 | 31.4 | 21.8 | 3.3 | 28.8 |
| Standard Deviation | | 2.2 | -- | 31.4 | 34.0 | 37.5 | 40.5 | 34.4 | -- | 42.0 |

^aBDL = Below analytical detection limit

-- = Not measured

TABLE B-7. PERCENT ARSENIC (BY WEIGHT) IN UNCONTROLLED
INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 76.2 | 3.7 | 6.5 | 13.6 |
| MERL B | 24 | --- | --- | --- | --- |
| MERL C | 24 | 41.9 | 20.5 | 21.0 | 16.6 |
| MERL D | 24 | 14.0 | 8.9 | 74.6 | 2.5 |
| MERL E | 24 | 56.3 | 0.9 | 0.7 | 42.1 |
| MERL F | 24 | 33.5 | 39.5 | 17.2 | 9.8 |
| MERL K | 24 | 16.8 | 39.0 | 19.3 | 24.9 |
| WERL A | 30 | 61.5 | 30.5 | 2.2 | 5.8 |
| WERL B | 30 | 57.8 | 29.2 | 4.3 | 8.7 |
| Average | | 44.8 | 21.5 | 18.2 | 15.5 |
| Standard Deviation | | 20.8 | 15.5 | 24.2 | 12.8 |

TABLE B-8. PERCENT CADMIUM (BY WEIGHT) IN UNCONTROLLED
INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 46.1 | 3.3 | 15.9 | 34.7 |
| MERL B | 24 | | | | |
| MERL C | 24 | 7.6 | 3.2 | 4.3 | 84.9 |
| MERL D | 24 | 55.1 | 23.1 | 4.7 | 17.0 |
| MERL E | 24 | 18.2 | 0.4 | 0.7 | 80.7 |
| MERL F | 24 | 1.4 | 0.9 | 0.7 | 97.0 |
| MERL K | 24 | 24.0 | 36.2 | 18.0 | 21.8 |
| WERL A | 30 | 28.2 | 44.4 | 11.4 | 16.0 |
| WERL B | 30 | 17.5 | 25.8 | 7.0 | 49.7 |
| Average | | 24.8 | 17.2 | 7.8 | 50.2 |
| Standard Deviation | | 18.2 | 17.5 | 6.6 | 33.0 |

TABLE B-9. PERCENT COPPER (BY WEIGHT) IN UNCONTROLLED
INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 63.0 | 4.1 | 14.1 | 18.5 |
| MERL B | 24 | | | | |
| MERL C | 24 | 11.6 | 67.5 | 3.2 | 17.7 |
| MERL D | 24 | 74.1 | 12.4 | 4.4 | 9.1 |
| MERL E | 24 | 53.8 | 1.2 | 0.7 | 44.3 |
| MERL F | 24 | 34.8 | 23.9 | 8.2 | 33.1 |
| MERL K | 24 | 24.3 | 50.5 | 18.2 | 7.0 |
| WERL A | 30 | 43.8 | 45.8 | 3.1 | 7.3 |
| WERL B | 30 | 48.5 | 28.9 | 4.8 | 17.8 |
| Average | | 44.2 | 29.3 | 7.1 | 19.4 |
| Standard Deviation | | 20.4 | 23.7 | 6.1 | 13.2 |

TABLE B-10. PERCENT CHROMIUM (BY WEIGHT) IN UNCONTROLLED
INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 66.2 | 3.7 | 12.1 | 18.0 |
| MERL B | 24 | | | | |
| MERL C | 24 | 34.8 | 18.3 | 8.6 | 38.3 |
| MERL D | 24 | 76.7 | 19.2 | 3.6 | 0.5 |
| MERL E | 24 | 84.1 | 3.0 | 1.5 | 11.4 |
| MERL F | 24 | 54.0 | 28.6 | 12.7 | 4.7 |
| MERL K | 24 | 36.2 | 38.4 | 17.4 | 8.0 |
| WERL A | 30 | 39.5 | 36.1 | 1.8 | 22.6 |
| WERL B | 30 | 9.3 | 5.2 | 0.9 | 84.6 |
| Average | | 50.1 | 19.1 | 7.3 | 23.5 |
| Standard Deviation | | 24.9 | 14.4 | 6.3 | 27.4 |

TABLE B-11. PERCENT LEAD (BY WEIGHT) IN UNCONTROLLED
INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 58.7 | 3.6 | 14.6 | 23.1 |
| MERL B | 24 | | | | |
| MERL C | 24 | 20.3 | 27.2 | 7.3 | 45.2 |
| MERL D | 24 | 66.3 | 12.2 | 4.5 | 17.0 |
| MERL E | 24 | 5.3 | 0.0 | 0.3 | 94.4 |
| MERL F | 24 | 11.9 | 10.1 | 11.3 | 66.7 |
| MERL K | 24 | 15.8 | 32.8 | 17.0 | 34.4 |
| WERL A | 30 | 29.1 | 47.0 | 3.3 | 20.6 |
| WERL B | 30 | 20.1 | 21.3 | 5.9 | 52.7 |
| Average | | 28.4 | 19.3 | 8.0 | 44.3 |
| Standard Deviation | | 22.2 | 15.9 | 5.8 | 26.6 |

TABLE B-12. PERCENT NICKEL (BY WEIGHT) IN UNCONTROLLED INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 65.2 | 3.8 | 12.4 | 18.6 |
| MERL B | 24 | | | | |
| MERL C | 24 | 35.7 | 19.3 | 8.4 | 36.6 |
| MERL D | 24 | 55.5 | 37.5 | 5.6 | 1.4 |
| MERL E | 24 | 78.4 | 1.6 | 1.7 | 18.3 |
| MERL F | 24 | 59.4 | 29.3 | 9.6 | 1.7 |
| MERL K | 24 | 31.6 | 41.2 | 15.8 | 11.4 |
| WERL A | 30 | 33.4 | 45.3 | 2.9 | 18.4 |
| WERL B | 30 | 8.7 | 6.4 | 1.3 | 83.6 |
| Average | | 46.0 | 23.0 | 7.2 | 23.8 |
| Standard Deviation | | 22.5 | 17.7 | 5.3 | 26.6 |

TABLE B-13. PERCENT SELENIUM (BY WEIGHT) IN UNCONTROLLED
 INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|-------------------|-----------|---------|-------------|------------|----------|
| WERL B | 30 | 0.0 | 22.2 | 0.0 | 77.8 |

TABLE B-14. PERCENT ZINC (BY WEIGHT) IN UNCONTROLLED
INCINERATOR EXHAUST GASES BY PARTICLE SIZE

| Name/ Location | Reference | > 10 um | 3.5 - 10 um | 1 - 3.5 um | < 1.0 um |
|--------------------|-----------|---------|-------------|------------|----------|
| MERL A | 24 | 62.8 | 3.7 | 14.5 | 19.0 |
| MERL B | 24 | | | | |
| MERL C | 24 | 24.5 | 25.9 | 6.6 | 43.0 |
| MERL D | 24 | 73.2 | 19.0 | 3.8 | 4.0 |
| MERL E | 24 | 29.1 | 0.5 | 0.5 | 69.9 |
| MERL F | 24 | 31.6 | 29.5 | 9.7 | 29.2 |
| MERL K | 24 | 20.7 | 39.6 | 16.2 | 23.5 |
| WERL A | 30 | 44.4 | 46.1 | 2.7 | 6.8 |
| WERL B | 30 | 50.0 | 30.0 | 4.6 | 15.4 |
| Average | | 42.0 | 24.3 | 7.3 | 26.4 |
| Standard Deviation | | 19.0 | 16.0 | 5.7 | 21.5 |

TABLE B-15. SUMMARY OF INCINERATOR AND SCRUBBER OPERATING PARAMETERS, FIELDS POINT SEWAGE SLUDGE INCINERATOR, JULY 1982

| Date | Sludge Charge | | Hours per Day Sludge Charged To Incinerator | Hearth #1 | | Hearth #4 | | Hearth #5 | | Hearth #6 | | Number of Hours per Day 1400 F Achieved | Scrubbing System | | | |
|---------|-----------------------------|-----|---|-----------|--------------------|-----------|------|--------------------|------|-----------|--------------------|--|---------------------|------|----------------|-----|
| | Rate Range (Wet Tons/Hr) | Low | | High | Temp. Range (F) | Low | High | Temp. Range (F) | Low | High | Temp. Range (F) | | Low | High | ΔP in. W.G. | Low |
| | High | | | | | | | | | | | | | | | |
| 7-2-82 | 4.0 | 0.8 | 15 | 1050 | 610 | 1520 | 960 | 1090 | 980 | 950 | 580 | 3 | 41.2 | 11.0 | | |
| 7-3-82 | 4.0 | 2.0 | 24 | 850 | 600 | 1220 | 810 | 1120 | 920 | 1040 | 680 | 0 | 43.2 | 14.6 | | |
| 7-4-82 | 4.5 | 1.2 | 21 | 960 | 600 | 1400 | 870 | 1200 | 920 | 1150 | 530 | 1 | 35.8 | 23.8 | | |
| 7-5-82 | 4.5 | 0.3 | 23 | 870 | 520 | 1320 | 740 | 1300 | 900 | 1030 | 710 | 0 | 41.6 | 0 | | |
| 7-9-82 | 6.5 | 0 | 5 | 700 | 680 | 1100 | 1000 | 1520 | 1300 | 1520 | 780 | 3 | 23.3 | 0 | | |
| 7-11-82 | a | a | a | 1110 | 670 | 1710 | 1050 | 1460 | 1020 | 1620 | 910 | 9 | 17.6 | 0 | | |
| 7-13-82 | a | a | a | 790 | 550 | 2020 | 800 | 2030 | 850 | 1500 | 510 | 2 | 42.6 | 0 | | |
| 7-15-82 | 8.0 | 1.2 | 18 | 800 | 510 | 1050 | 640 | 1400 | 580 | 1400 | 650 | 1 | 35.3 | 0 | | |
| 7-16-82 | 7.0 | 2.0 | 24 | 650 | 510 | 1020 | 550 | 1270 | 590 | 1450 | 680 | 2 | 37.2 | 28.8 | | |
| 7-17-82 | 5.0 | 0.5 | 23 | 820 | 550 | 1000 | 820 | 1200 | 830 | 1420 | 620 | 1 | 38.1 | 0 | | |
| 7-19-82 | 7.6 | 0.8 | 20 | 760 | 560 | 1140 | 710 | 1340 | 800 | 1420 | 730 | 2 | 43.0 | 0 | | |
| 7-21-82 | 8.0 | 1.0 | 22 | 770 | 530 | 1000 | 760 | 1480 | 830 | 1630 | 720 | 2 | 43.8 | 10.9 | | |
| 7-22-82 | 10.6 | 3.0 | 20 | 780 | 540 | 1140 | 710 | 1440 | 930 | 1600 | 780 | 5 | 43.2 | 14.0 | | |
| 7-23-82 | 7.1 | 2.9 | 24 | 820 | 550 | 1210 | 810 | 1180 | 920 | 1180 | 720 | 0 | 31.3 | 19.2 | | |
| 7-24-82 | 6.0 | 4.0 | 24 | 800 | 510 | 1030 | 800 | 1380 | 820 | 1580 | 620 | 2 | 30.2 | 23.0 | | |
| 7-25-82 | 5.7 | 0.3 | 18 | 960 | 520 | 1140 | 760 | 1280 | 1140 | 1050 | 620 | 0 | 35.5 | 0 | | |
| 7-26-82 | 6.1 | 1.7 | 24 | 850 | 540 | 1030 | 800 | 1340 | 1120 | 1500 | 620 | 2 | 30.9 | 22.3 | | |
| 7-27-82 | 5.1 | 1.4 | 18 | 680 | 520 | 960 | 790 | 1150 | 890 | 1100 | 470 | 0 | 35.4 | 23.5 | | |
| 7-28-82 | 7.7 | 2.9 | 24 | 980 | 520 | 1250 | 760 | 1300 | 970 | 1400 | 600 | 1 | 35.6 | 22.8 | | |
| 7-29-82 | 6.8 | 0.8 | 15 | 810 | 540 | 1160 | 850 | 1240 | 1080 | 1270 | 770 | 0 | 36.0 | 0 | | |
| 7-30-82 | 6.1 | 3.2 | 10 | 700 | 490 | 1050 | 730 | 1230 | 860 | 1300 | 650 | 0 | 32.0 | 20.8 | | |
| 7-31-82 | 5.6 | 3.8 | 6 | 700 | 610 | 1090 | 890 | 1270 | 1060 | 1330 | 980 | 0 | 28.0 | 23.0 | | |

^a Sludge scale and meter not operating.



APPENDIX C
EMISSION AND EXPOSURE MODELING

APPENDIX C
EMISSION AND EXPOSURE MODELING

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APPENDIX C EMISSION AND EXPOSURE MODELING

This Appendix discusses the air dispersion and exposure/risk assessment models and the modeling methodology used in the exposure/risk assessment analysis discussed in Section 4.0. Section 1.0 of the Appendix discusses the rationale for selecting the air dispersion and exposure/risk models used in the analysis. Section 2.0 discusses the methodology used to determine exposure/risk for carcinogenic pollutants. The methodology used to estimate exposure to non-carcinogenic pollutant emissions is discussed in Section 3.0.

C.1 MODEL SELECTION

The UNAMAP 6 version of the EPA approved Industrial Source Complex (ISC) air dispersion model, and the EPA Human Exposure Model (HEM) were used in the analysis.^{1,2} The ISC model is recommended in the Guidelines on Air Quality Models for estimating short-term and annual average concentrations from a continuous emission release at a stationary point source and includes an option to calculate the increase in ground level concentration caused by building wake effects.³ These ISC model options are necessary to determine ground level concentrations caused by emissions from the Cranston and Fields Point sewage sludge incinerators.

EPA's Human Exposure Model (HEM), which is used by EPA in setting all national emission standards for hazardous air pollutants (NESHAP) under Section 112 of the Clean Air Act, was used as the exposure/risk assessment model. By using the HEM model, exposure/risk results are consistent with the modeling protocols in official use by EPA in setting health-based regulations. The HEM model results can be directly compared with risk levels that EPA has previously determined to be unreasonable.

C.2 EXPOSURE/RISK MODELING METHODOLOGY FOR CARCINOGENIC POLLUTANTS

Figure C-1 shows the components of the HEM as it is currently applied in EPA exposure/risk studies. The model is comprised of two sub-models, one performs atmospheric dispersion analyses and the other performs exposure/risk analyses. Necessary inputs and computed outputs from the two sub-models are shown in Figure C-1. Basically, the dispersion sub-model accepts source and pollutant emission characteristics along with meteorological data and produces estimates of ground level concentrations at 160 receptor sites which are distributed within a radius of 50 km of the source. These ambient air concentrations are then coupled with a population distribution within the same area generated from data contained in US Census Bureau population files. By matching the ambient concentration with numbers of people, the HEM estimates both total or aggregate human exposure and the maximum human exposure (defined as the maximum concentration to which an individual is exposed).

The final computations performed by the HEM are the measures of risk. Exposure estimates have generally been combined with unit risk factors (URFs) derived from a linear, no threshold model to predict carcinogenic risk. The most probable upper bound estimate of total risk (number of cancer incidences expected in the population over a 70 year period), and maximum individual risk (the probability of the most exposed individual contracting cancer within a lifetime) are the risk measures calculated.

C.2.1 Atmospheric Dispersion Sub-model

The HEM is capable of utilizing an internal air dispersion model or accepting input comprised of the output concentrations from other EPA approved air dispersion models. ISCLT was used to predict the annual average concentration input required by the HEM model for these analyses. The ISCLT model is relatively sophisticated in terms of options associated with source, site, and pollutant characterization. For purposes of this study, default parameter values will be used for the majority of the options. Table C-1 lists the various options and the values used for each of the incinerator sites.

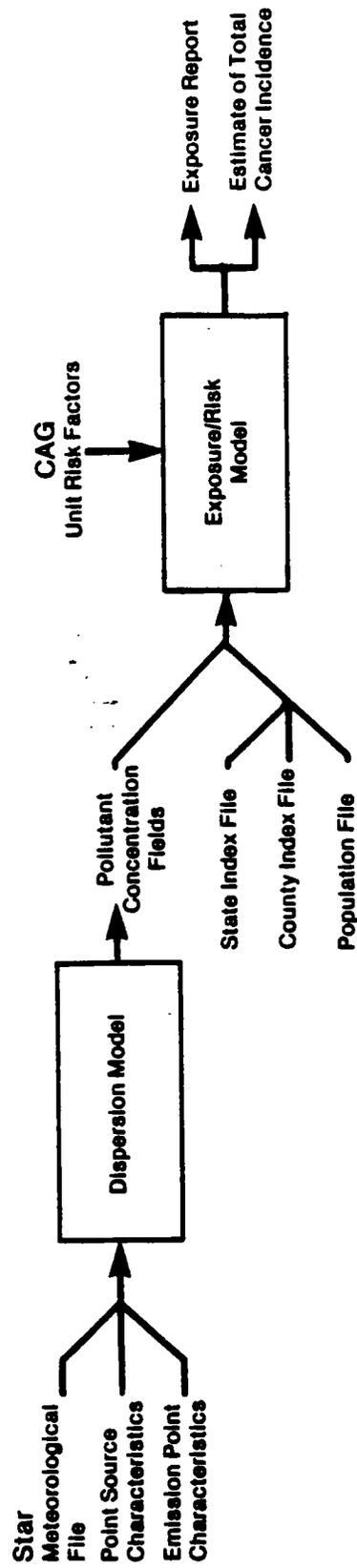


Figure C-1. Current Human Exposure Model (HEM) configuration.

TABLE C-1. ISCLT INPUT OPTIONS^a

| ISCLT OPTION | OPTION SELECTED |
|--|--|
| ● Receptor grid system | Polar grid extending to 50 km from the source. Ring distance will be located at .2, .3, .5, .7, 1.0, 2.0, 3.0, 4.0, 5.0, 7.5, 10.0, 20.0, 30.0, 40.0, and 50.0 kilometers. |
| ● Terrain type | Flat terrain. |
| ● Plume rise | Use the final plume rise option. |
| ● Correction for stack-tip downwash | Yes. |
| ● Site type | Rural. |
| ● Ambient air temperatures per stability class | Stability Class A-C 288 ⁰ K Stability Class D 283 ⁰ K Stability Class E-F 278 ⁰ K |
| ● Mixing layer heights | Stability Class A 1500 meters Stability Class B-D 1000 meters Stability Class E-F No Limit |
| ● Vertical potential temperature gradients | Default. 0 for stability Classes A-D .02 for stability Class E .035 for stability Class F |
| ● Height above ground at which wind speed was measured | 6.1 meters |
| ● Air entrainment coefficient for adiabatic or unstable atmosphere | Default (0.6). |
| ● Air entrainment coefficient for stable atmosphere | Default (0.6). |
| ● Coefficient of time dependent pollutant removal via physical or chemical processes | 0 |

TABLE C-1. (Continued)

| ISCLT OPTION | OPTION SELECTED | | | | | | | | | | | | | | | | | | |
|---|--|--------------------------|-----|-----|------|--|--|---|---|---|---|---|---|-----|-----|-----|-----|-----|------|
| ● Median values of wind speed per wind speed category | <table border="1"> <thead> <tr> <th colspan="6">Class (m/sec)</th> </tr> <tr> <th>1</th> <th>2</th> <th>3</th> <th>4</th> <th>5</th> <th>6</th> </tr> </thead> <tbody> <tr> <td>1.5</td> <td>2.5</td> <td>4.3</td> <td>6.8</td> <td>9.5</td> <td>12.5</td> </tr> </tbody> </table> | Class (m/sec) | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 1.5 | 2.5 | 4.3 | 6.8 | 9.5 | 12.5 |
| Class (m/sec) | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | | | | | | |
| 1.5 | 2.5 | 4.3 | 6.8 | 9.5 | 12.5 | | | | | | | | | | | | | | |
| ● Wind speed power law exponent as function of wind speed and stability class | <table border="1"> <thead> <tr> <th colspan="6">Wind Speed Class (Rural)</th> </tr> <tr> <th>1</th> <th>2</th> <th>3</th> <th>4</th> <th>5</th> <th>6</th> </tr> </thead> <tbody> <tr> <td>.07</td> <td>.07</td> <td>.10</td> <td>.15</td> <td>.35</td> <td>.55</td> </tr> </tbody> </table> | Wind Speed Class (Rural) | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | .07 | .07 | .10 | .15 | .35 | .55 |
| Wind Speed Class (Rural) | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | | | | | | |
| .07 | .07 | .10 | .15 | .35 | .55 | | | | | | | | | | | | | | |
| ● Building wake effects | Perform a GEP stack height analysis for each incinerator and model building wake effects if the stack height is below GEP. NOTE: building wake effects are modeled. | | | | | | | | | | | | | | | | | | |
| ● Meteorological data | STAR data for the Providence/Francis/Green NWS site for the years 1968 to 1972 will be used. The STAR data will be supplied by John Pollack. | | | | | | | | | | | | | | | | | | |

^a Model options will be the same for each site and are based on recommendations discussed in the Guidelines on Air Quality Models (Revised, 1986), the Second Edition of the Industrial Source Complex (ISC) User's Guide, and the User's Manual for the Human Exposure Model (HEM).

Meteorological data required for running the model include annual joint frequency of occurrence values for wind speed, wind direction, and atmospheric stability class, referred to as Stability Array (STAR) data. National Climatic Data Center. STAR data developed from surface and upper air data from the Providence/Francis/Green National Weather Service site for the five year period from 1968 to 1972 were used in this analysis. This data was supplied to Radian by the Rhode Island DEM.

Figure C-2 illustrates the typical polar grid system used by ISCLT to communicate pollutant concentration to the exposure sub-model. Pollutant concentrations were estimated at 160 receptor sites located along radial lines extending from the source to 50 km in each of 16 directions. The receptor sites are at the intersection of the 16 compass directions and concentric circles representing 10 distances from the source. The ring distances selected for this analysis are 0.2, 0.5, 1, 2, 5, 10, 20, 20, 40, and 50 km from the source.

C.2.2 EXPOSURE/RISK SUB-MODEL

The exposure/risk sub-model consists of three functions: area population characteristics, pollutant concentration/population matching (estimation of exposure), and risk estimation. These three functions of the HEM exposure/risk sub-model are described in the following subsections.

C.2.2.1 Population Characterization

The HEM accesses a modified version of the general population file maintained by the Census Bureau referred to as the Master Area Reference File (MARF). Contained in this data base are total population counts for each block group/enumeration district (BG/ED) within the U.S. BG/EDs represent geographic areas containing approximately 1,600 people. Each BG/ED is located by a latitude and longitude representing its geographic centroid. The HEM contains a series of algorithms to determine which BG/EDs

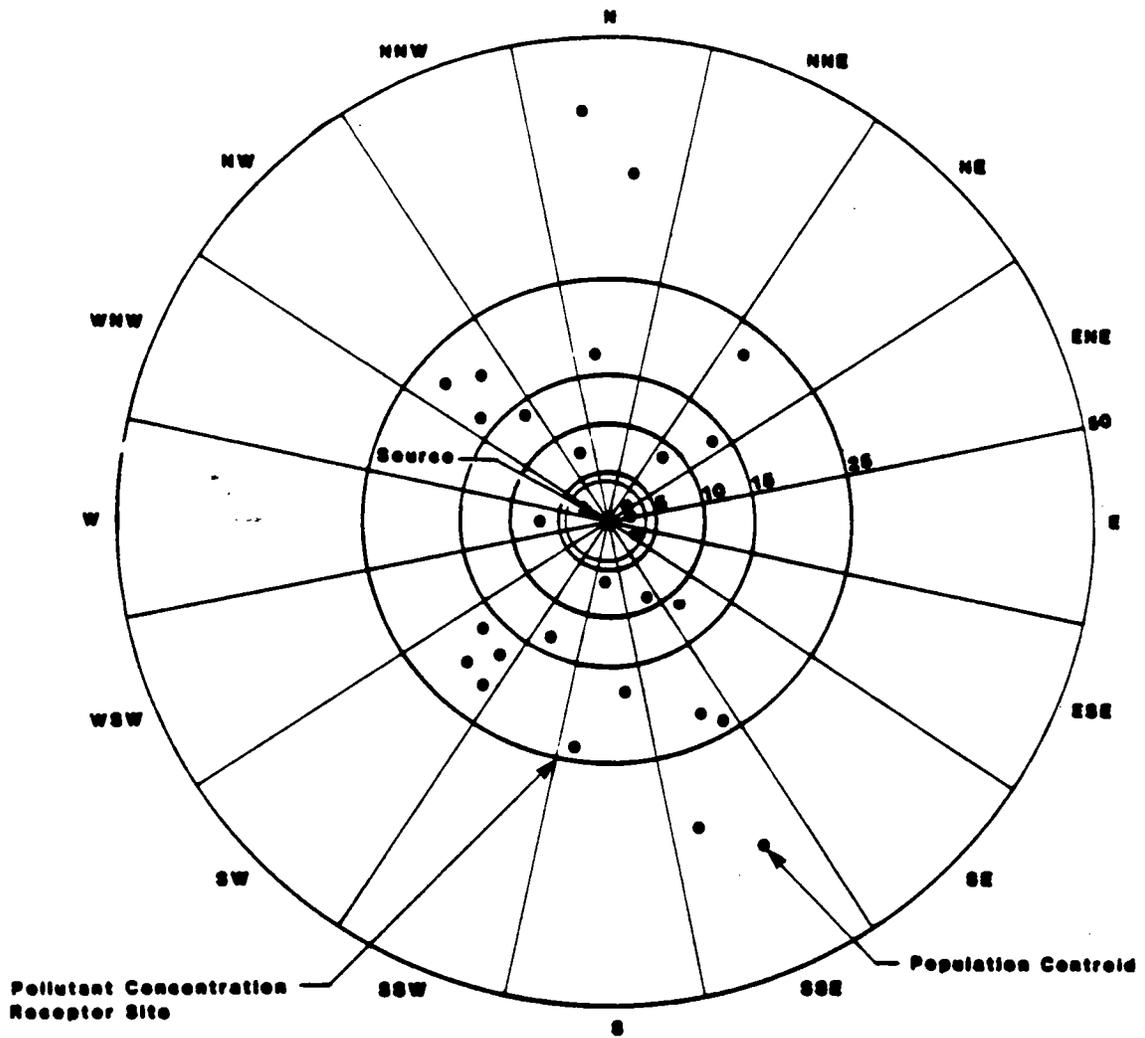


Figure C-2. Human Exposure Model (HEM) polar grid.

are located within 50 km of the source. Figure C-2 illustrates an example distribution of BG/EDs overlaid on the pollutant concentration grid. The HEM assumes that all individuals are permanently located at the BG/ED centroid.

C.2.2.2 Exposure Estimation

The exposure methodology matches pollutant concentrations with populations to determine exposures. The HEM employs two concentration/population matching schemes, one for population centroids relatively distant from the source and a second for those centroids near the source. The basis for these two schemes is the relationship between the geographic size of a BG/ED and the area associated with a pollutant receptor site. Within 3.5 km of the source, the area covered by a BG/ED area is relatively large and could cover more than one receptor site. Here, the HEM employs a scheme to allocate the population of a BG/ED among nearby receptor sites. At distances greater than 3.5 km from the source, concentrations are simply interpolated from the dispersion model output receptors to the BG/ED centroid. The result of each of these schemes is to match a single concentration to each population grouping, thus allowing exposure to be computed.

The HEM computes three measures of exposure: maximum individual exposure, cumulative exposures by concentration level and aggregate exposure. Each of these measures of exposure is defined below:

1. Maximum individual exposure is defined as the highest concentration to which a population has been matched.
2. Cumulative exposure by concentration level is the total number of people exposed so concentrations greater than or equal to a specified concentration. It is expressed as:

$$\text{Total Exposure at Concentration Level } L = \sum_{i=1}^N P_i C_i S_i(C_i, L)$$

($\mu\text{g}/\text{m}^3$ x persons)

where:

L = A particular concentration of interest

P_i = Total population assigned to location i

C_i = Pollutant concentration computed for location i

S_i = 0, if $C_i < L$
1, if $C_i \geq L$

N = Number of locations containing both a concentration value and a population count

3. Aggregate exposure ($\mu\text{g}/\text{m}^3 \times \text{persons}$) is simply the sum of exposures computed at each concentration level L .

C.3 EXPOSURE MODELING METHODOLOGY FOR NONCARCINOGENIC POLLUTANTS

The ISCST and ISCLT air dispersion models were used to determine the short-term and long-term exposure levels for noncarcinogenic pollutants. Annual average concentrations were calculated using the ISCLT model and a 1 gram per second emission rate. The model options, receptor locations, and meteorological data input to the ISCLT model were identical to those discussed in Section C.2 of this Appendix. The annual average concentration for a specific pollutant was calculated by multiplying the concentration predicted using the 1 gram per second emission rate by the actual pollutant emission rate.

The ISCST air dispersion model was used to determine 24-hour average ground level concentrations from each incinerator. The building downwash screening procedure used to discussed in Appendix C of the Regional Workshops on Air Quality Modeling: A Summary Report was used to perform the short-term modeling.⁴ A maximum 1-hour average concentration was predicted using a 1 gram per second emission rate. The 24-hour average concentration was calculated by multiplying the 1-hour average concentration by a factor of 0.4 as recommended in the Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10R.⁵ The 24-hour average concentration calculated using a 1 gram per second emission rate was multiplied by the pollutant specific emission rate to determine the actual 24-hour average pollutant concentration.

The building downwash screening procedure in the Workshop report discusses the application of ISCST in the screening mode. Receptors were located every 100 meters along a single radial out to a distance of 2000 meters. Meteorological data input included combinations of wind speed and stability class suggested in the Workshop report. An ambient temperature of 294⁰K, a mixing height of 5000 meters, and a wind direction along the line of receptors was used for each hour of representative "worst-case" meteorological data. The building dimensions input for each incinerator were those used in the ISCLT modeling analysis discussed in Section 4.0 of the report.

C.4 REFERENCES

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