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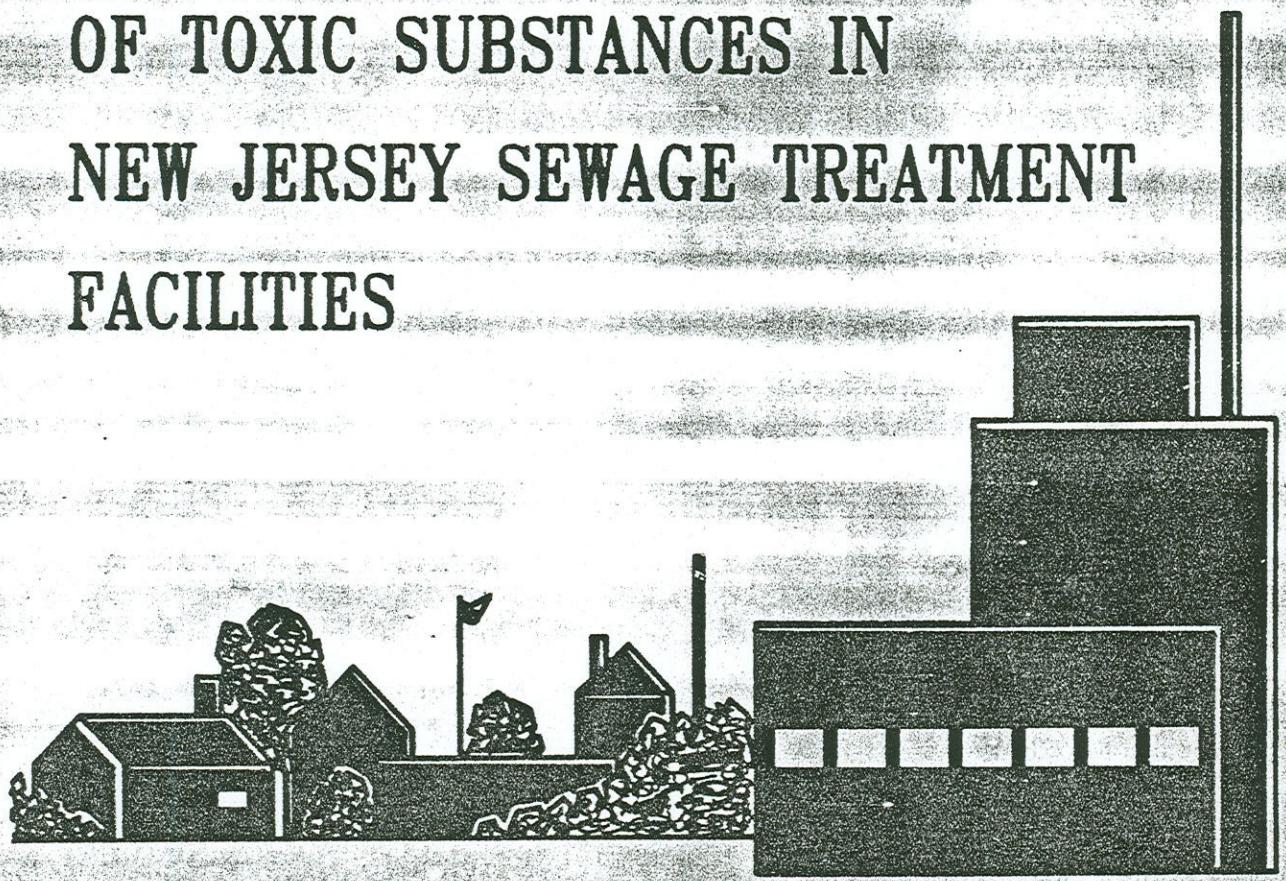
NJ Department of Environmental Protection

THE OCCURRENCE AND FATE OF TOXIC SUBSTANCES IN NEW JERSEY SEWAGE TREATMENT FACILITIES



Office of Science and Research

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The Occurrence and Fate of Toxic Substances in New Jersey Sewage Treatment Facilities

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Executive Summary

This report is a summary of work performed by the Office of Science and Research (OSR) within the New Jersey Department of Environmental Protection (DEP) to investigate the occurrence, effects, and fate of toxic substances discharged to selected New Jersey Publicly Owned Treatment Works (POTWs).

In 1982, samples taken from a POTW in northeast New Jersey revealed that the levels of priority pollutants in the effluent substantially exceeded the mean levels detected in an OSR survey of 31 industrial effluents throughout the state. Also, a comparison of the effluent values from this POTW with the influent results indicated that the plant did not remove these priority pollutants.

Based upon these findings, a multidisciplinary study of New Jersey POTWs was designed by the Office of Science and Research in cooperation with DEP's Division of Water Resources (DWR). In addition to the sampling of wastewater and sludge from ten plants in the initial phase of this study, Ames mutagenicity testing, air sampling for volatile organics, and 96-hour flow-through fish bioassays were conducted at selected plants.

The results from the chemical analyses conducted during this study confirmed that POTWs receive large quantities of priority pollutants. The mean influent concentration of total priority pollutants was 3612 ug/l (parts per billion) ranging from 248-12,557 ug/l for each individual plant. The most frequently occurring compound groups were volatile organics and metals. Together, they accounted for 82% of the total priority pollutant concentration.

Effluent chemical analyses detected a mean priority pollutant concentration of 2080 ug/l. These values ranged from 86-8965 ug/l. As with the influents, volatile organic compounds and metals accounted for the majority of the total priority pollutant load (78%). A comparison of influent and effluent concentrations revealed that primary POTWs removed an average of 25% of the influent priority pollutant concentration, while POTW's with secondary treatment removed an average of 73%.

Chemical analyses revealed that many of these pollutants were concentrated in the final sludge. A mean priority pollutant concentration of 5323 mg/kg (parts per million) was detected with a range from 2,361-23,765 mg/kg. Metals accounted for 88% of the total priority pollutant concentration in the sludge. Benzene and toluene were the most frequently detected volatile compounds in the wastewater and sludge, and were detected at the highest mean concentrations. The phthalate esters, particularly bis(2-ethylhexyl) phthalate, were the most frequently detected base/neutral compounds. Compounds in the PCBs/pesticides, and phenol analytical groups were detected infrequently. Copper, lead, and zinc were among the most frequently occurring metals, and also found at the highest mean concentrations.

The analytical results of this study are compared with those of an 1982 U.S. Environmental Protection Agency (EPA) project in which priority pollutant analyses were performed at fifty POTWs throughout the United States. In general, there was agreement between the New Jersey and EPA studies regarding the types and concentrations of detected compounds in the various media.

Overall, the effluent wastewater analyses indicated a decrease in both the average total concentration and number of priority pollutants from those found in the influent sample analyses. A comparison of facility designs, showed that plants with secondary treatment achieved slightly higher removal efficiencies than the primary plants. This is probably due to improved solids removal, biological degradation, and greater aeration resulting in increased volatilization of compounds.

Ames mutagenicity testing was performed on influent and effluent samples collected at eight plants. Mutagenic activity was not detected in the majority of samples. Two of the eight effluent samples (25%) were positive in the Ames assay. This was lower than the 39% positive samples found in a previous survey of direct industrial discharges (McGeorge et al., 1983).

Ninety-six hour flow-through fish bioassays were conducted by DWR at three POTWs. Two of these sites failed to meet the regulatory requirement (N.J.A.C. 7:9-5.1 et seq.) that the LC50 not exceed 50%. There was no apparent correlation between this bioassay and priority pollutant concentrations or Ames results.

Volatile organic analyses of air samples collected near the influent wastewater sampling locations were performed at four facilities. The results of these analyses showed strong relationships to volatile organics detected in the wastewater.

As a follow-up to this project, another study of New Jersey POTWs was conducted. In this second phase, twelve plants were chosen and final sludge was collected three times during a six month period. These plants included the six New Jersey sites which were disposing of sludge in the ocean. The results of this work are also presented in the report and correlate well with the initial sludge results.

The study results demonstrate that POTWs receive and discharge priority pollutants and support continued implementation of pretreatment programs that remove these substances at the industrial source. These data also confirm the continued need to upgrade existing primary sewage treatment facilities.

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I. Introduction

A. Background

Publicly owned treatment works (POTWs) are typically designed to treat sewage and household wastes. The treatment processes are not efficient with regard to the removal of many toxic substances (Hammer, 1975; Metalf and Eddy, 1972; Petrasek 1983). A number of factors have led to increasing concern over the levels of toxic substances which are introduced to and emitted from POTWs. Many industries are finding it cost effective to discharge their wastes to POTWs, rather than upgrade or construct new on-site treatment systems. Under Resource Conservation Recovery Act (RCRA), the Domestic Sewer Exclusion, (DSE), provides that a hazardous waste, when mixed with domestic sewage, is no longer considered a hazardous waste. The exclusion allows industries connected to POTWs to discharge hazardous wastes to sewers containing domestic sewage without having to comply with certain RCRA generating requirements, such as manifesting and reporting. In addition, POTWs receiving DSE wastes are not deemed to have received hazardous wastes and, therefore, not subject to RCRA treatment, storage, and disposal facility requirements (USEPA, 1986). EPA intended that pretreatment would control these wastes. Also, as New Jersey continues to implement its hazardous waste site cleanup program, the option of discharging leachate and contaminated groundwater to POTWs has often been determined to be the most economical solution. Furthermore, the New Jersey Department of Environmental Protection has found that several fish species are bioaccumulating PCBs and other chlorinated organics which may originate, in part, from POTW discharges (Belton et al., 1982 & 1983).

The Office of Science and Research (OSR) became actively involved with research concerning toxic substances in POTWs in June 1982. At this time, the Rutherford Health Officer expressed concern about potential public health impacts from odors emanating from the Rutherford/E. Rutherford/Carlstadt Joint Meeting Sewage Treatment Plant. Wastewater samples analyzed from the plant showed the facility to be ineffective in the treatment of priority pollutants. Relatively high concentrations of these toxic substances were detected in the effluent.

During 1982, EPA published a document entitled "Fate of Priority Pollutants in Publicly Owned Treatment Works" (USEPA, 1982). This study of influents, effluents, and sludges from fifty POTWs throughout the United States identified a large number of priority pollutants in these media, many at significant levels.

In a related wastewater study conducted between 1981 and 1983, OSR sampled and analyzed 31 industrial effluents. The facilities had been identified by OSR's Industrial Survey to be using and possibly discharging toxic materials in their effluents. Generally, the levels of priority pollutants detected at these industrial facilities were lower than both the initial OSR sampling at the Rutherford Sewage Treatment Plant (STP), and many of the sewage treatment plants in the EPA study.

Based on the information provided by these studies, it was decided that a research study of the occurrence and fate of priority pollutants in New Jersey POTWs was needed. Rather than duplicate the EPA study, a multidisciplinary approach was designed to provide better insight into the overall fate and effects of priority pollutants at these facilities. In addition to chemical analyses of influent, effluent, and sludge samples, Ames mutagenicity testing, 96-hour flow-through fish bioassays, and air sampling for volatile organics, were conducted at selected plants. Biological testing was included in the OSR study because priority pollutant analyses can detect only a fraction of the toxic constituents which may be present in wastewater. This limitation was illustrated by previous OSR Ames mutagenicity testing of 31 industrial wastewaters, which detected mutagenic activity in wastewaters containing few or no organic priority pollutants.

B. Description of Studies

POTW Study - This study was designed to determine the extent that toxic pollutants are discharged to representative New Jersey sewage treatment facilities and explore the fate and potential impacts of these toxic substances. Particular emphasis was placed on a multidisciplinary approach. A variety of sample types were collected at ten POTWs located throughout the state (Figure 1). Samples were analyzed using a variety of testing techniques described in Section II. The project was designed cooperatively by representatives from several units within OSR and the Division of Water Resources (DWR). Sampling, which was completed between April and September 1983, was conducted primarily by OSR staff. The various analyses, with the exception of the fish bioassay, were completed by contract laboratories. Priority pollutant analyses of influent, effluent, and sludge samples were conducted by Rutgers University, Department of Environmental Science. The Ames mutagenicity test was conducted by the Institute for Medical Research on eight wastewater influent and effluent samples. Fish bioassays measuring lethality as the toxic end points were conducted by the DWR, Biological Services Section, on three of the ten effluents. Simultaneous volatile organic air sampling was performed using the OSR Mobile Monitoring Unit at four of the ten facilities. Table 1 lists the analyses that were conducted at each facility.

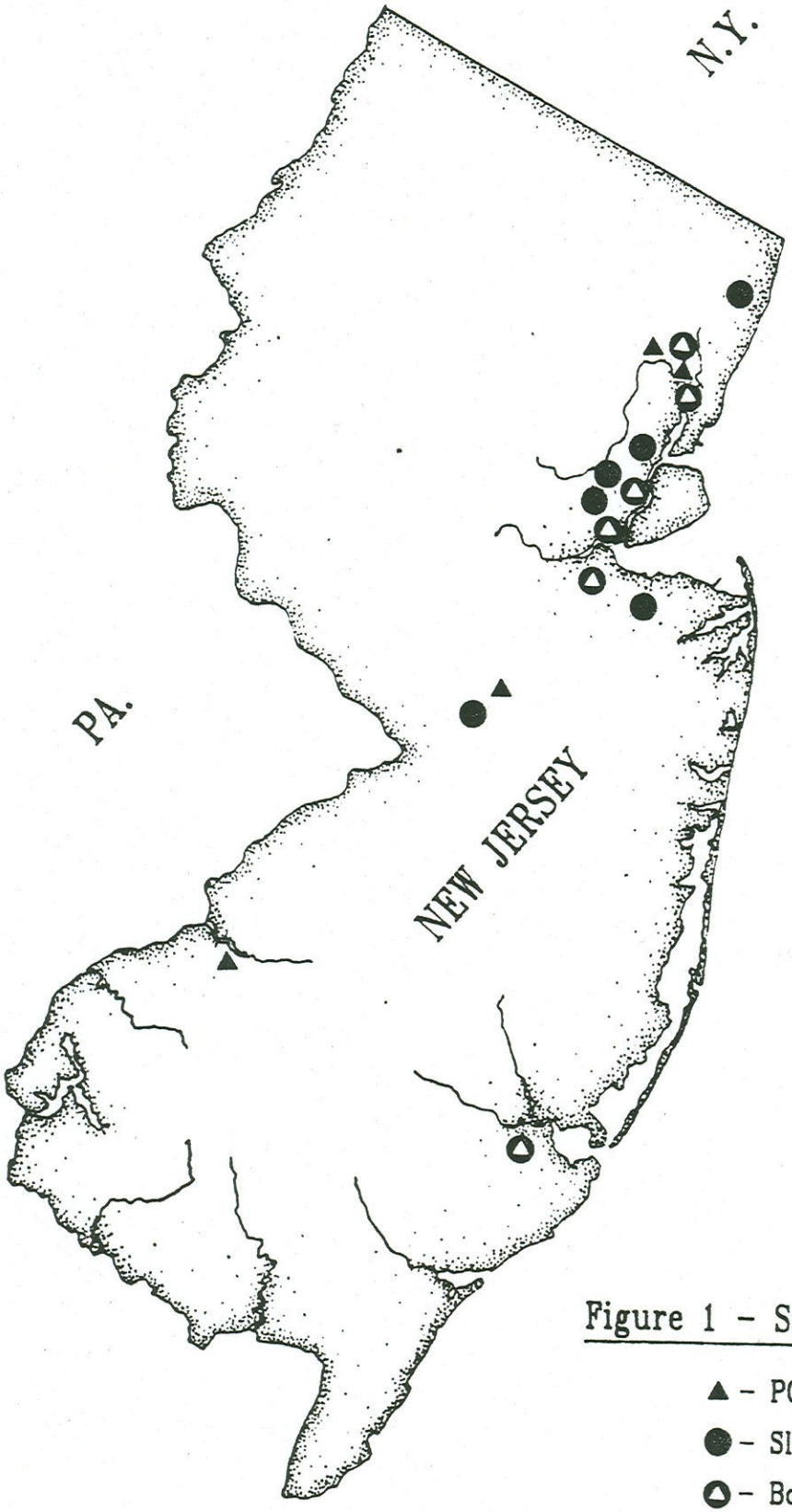

Figure 1 – Sampling Locations

▲ – POTW Study

● – Sludge Study

◬ – Both Studies

Table 1. Testing Conducted at POTWs

	WASTEWATER Influent and Effluent Priority Pollutants	AMES TEST Influent and Effluent	FISH BIOASSAY Effluent	SLUDGE Priority Pollutants	AIR MONITORING Volatile Organic Analyses
Atlantic County MUA	X	X		X	
Gloucester County MUA	X			X	
Hightstown Borough STP	X	X	X	X	X
Kearny Municipal STP	X	X		X	X
Middlesex County UA	X			X	X
N. Arlington-Lyndhurst STP	X	X	X	X	
Passaic Valley Sewerage Commission	X	X		X	
Perth Amboy STP	X	X		X	
Rutherford/E. Rutherford Carlstadt Joint Meeting STP	X	X		X	X
Totowa West End STP	X	X	X	X	

Sludge Study - After reviewing the initial chemical results from the POTW study, it was apparent that many priority pollutants were being concentrated in sewage sludges. To investigate this further, an additional sludge study was designed. A series of three sludge samples were collected from a total of 12 POTWs between September 1983 and January 1984. Six of the 12 plants were resampled from the first study. The analytical results from the sludge study are reported separately in the Results section.

II. Project Design and Methodologies

A. Plant Selection and Characteristics

POTW Study - The ten facilities included in this project were selected on the basis of the following criteria:

- Percent industrial flow - A wide range in the percentage of industrial contribution was chosen. Estimated industrial contribution ranged from 0 to 80%.

- Treatment processes - 4 primary and 6 secondary plants were selected to compare the removal efficiencies of different types of treatment.

- Type of industrial contribution - Certain industries use classes of compounds known to be toxic and/or mutagenic. Facilities receiving flows from these industries were included to assess the fate of these compounds within the POTWs.

- Geographic distribution - The majority (7) of selected POTWs were located in northeast New Jersey. Several plants were chosen in central and southern New Jersey in order to obtain a geographical mix.

- POTW size - Using 5 million gallons per day (MGD) as a delineation between small and large, five small plants were selected with design flows ranging from .38 to 5 MGD, and five large plants were chosen with flows ranging from 10 to 225 MGD.

Pertinent characteristics of the POTWs sampled in this study are summarized in Table 2, including information on flow rates, treatment, and industrial contribution.

Sludge Study - Sludges from a total of twelve facilities were sampled in the follow-up sludge study. Six of the plants sampled for the POTW study were included in the sludge follow-up project. This project focused on treatment facilities with a variety of sludge disposal methods. OSR sampled all 6 New Jersey POTWs that were permitted for the ocean dumping of sewage sludges. Table 3 lists these facilities and the amounts of sludge disposal in wet tons per year.

Table 2. POTW Characteristics

	Flow		Estimated Retention Time (Hr)[2]	Treatment Process	Estimated Percent Industrial Flow[3]	Major Industrial Contributor(s)
	Actual (MGD)[1]	Design (MGD)				
Atlantic County	26.1	40.0	8-10	2° Act. Sludge	0	None
Gloucester	21.4	16.5	8	2° Act. Sludge	20	Polypropylene manufacturing
Hightstown	.88	1.2	6	2° Trickling Filter	5	Lighting and paint manufacturing
Kearny	1.33	4.0	3	1°	80	Chemical manufacturing
Middlesex	108	120	4	2° Pure-ox	30	Pharmaceutical, yeast, paper processing, and chemical manufacturing
N. Arlington-Lyndhurst	1.1	2.0	4	1°	15	Textile, machine shops & general manufacturing
Passaic	239	225	4	2° (no 1° settling)	25	Over 300 industrial connections; large number are textile and dye manufacturing
Perth Amboy	4.0	10	2	1°	50	Stearate, surfactant, polyester, and asphalt roofing manufacturing
Rutherford	4.3		2	1°	50	Varied industrial input
Totowa	.86	.38	5	2° Trickling Filter	25	Pharmaceutical, textile, printing, fragrance, and chemical manufacture

1. MGD = Million Gallons per Day
2. Retention time is an estimated value provided by treatment plant operator.
3. Percent industrial flow estimate was provided by the DWR, Industrial Pretreatment Section.

Table 3 POTWs Included in Sludge Study

Facility	Wet Tons/Year	Disposal Method
Middlesex County Sewerage Authority	900,000	Ocean Dumping
Passaic Valley Sewerage Commissioners	1,100,000	Ocean Dumping
Rahway Valley Sewerage Authority	200,000	Ocean Dumping
Linden-Roselle Sewerage Authority	125,000	Ocean Dumping
Essex-Union Sewage Authority	475,000	Ocean Dumping
Bergen County Sewage Authority	290,000	Ocean Dumping
Atlantic County Sewage Authority	109,500	Incineration
Bayshore Regional Sewerage Authority	68,300	Incineration
Kearny Wastewater Treatment Plant	8,600	Landfill
Perth Amboy Sewage Treatment Plant	64,200	Landfill
Rutherford-E. Rutherford-Carlstadt Joint Meeting Sewage Treatment Plant	13,900	Landfill
East Windsor Municipal Utilities Authority	14,000	Land Application

B. Sampling Procedures

Wastewater Priority Pollutant and Ames Analyses - Composite samples were collected at the NJPDES influent and effluent sampling locations at each of the ten facilities. Wastewater volumes of 160 ml were collected every 15 minutes over a 24-hour period, for a total volume of 15 liters. Samples for both priority pollutant testing and Ames mutagenicity analyses were collected in the same container and split in the field prior to preservation and transport to the laboratories. Approximately ten liters of wastewater were utilizied for Ames testing and five liters for chemical analyses.

A Manning 3000T composite sampler was used to collect the wastewater samples. This sampler is specifically designed for the measurement of toxic pollutants in water, and all parts that are in contact with the sample are composed of teflon or glass. The sampler and the receiving bottles were cleaned prior to use by the passage of sequential solvents through the tubing and all internal parts of the apparatus. Three washes of each of the following were performed in sequence: detergent (Alconox), tap water, reagent grade acetone, and distilled water. Areas of the sampler that might to retain residual matter were scrubbed after the detergent rinse. The final step of the cleaning procedure involved the purging of two samples of wastewater through the sampler into the receiving bottle. This wastewater was used to rinse the bottle and then discarded to the wastewater stream. Grab samples for volatile organics (VO) analyses were taken at the start and end of the composite sampling period.

Prior to commencement of sampling, an estimate of the wastewater detention time was obtained from plant operators. Influent and effluent sampling were then staggered to mimic the passage of wastewater through the plant. For the ten facilities, the detention time varied from one to eight hours.

Sludge - Samples were collected after sludge treatment, just prior to off-site disposal or incineration. Three discrete grab samples were mixed and composited at each of the ten POTWs. The samples were collected in laboratory-cleaned glass jars and were kept on ice during transport to the laboratory for analyses. The sampling methodology was identical for the follow-up sludge study, however, each of the twelve POTWs were sampled three times, at six week intervals.

Quality Assurance - For quality assurance purposes duplicate influent, effluent wastewater and sludge samples were collected and analyzed to assess laboratory precision. A field blank of distilled/deionized water was run through the composite sampler to assess possible contaminants from the sampling process.

Air - The OSR Mobile Monitoring Unit was utilized for air sampling at four of the ten facilities. Ambient air samples were collected near the influent wastewater sampling sites. Additional samples were collected in enclosed influent work areas at two facilities, where the potential for worker exposure was high. Twenty minute samples were collected using Nutech portable air samplers. These units concentrate volatile organic compounds onto a packed glass cartridge containing Tenax-GC. Details of sampling methodology can be obtained from OSR.

Fish Bioassay - 96-hour flow-through bioassays were conducted at three of the test facilities using the fathead minnow (Pimephales promelas Rafinesque) as the test organism. The bioassays were performed by DWR Biological Services Section personnel using a mobile on-site laboratory. All screening and flow-through testing followed methods established by NJDEP (N.J.A.C. 7:18:6.0 et seq.).

C. Testing Methodologies

Wastewater - The influent and effluent samples collected at the ten facilities were analyzed for priority pollutants by Rutgers University, Department of Environmental Science. Most of the chemical analyses followed USEPA methods. The compound groups analytical methods, and the corresponding USEPA method numbers are listed in Table 4.

Table 4. Chemical Analytical Methods

Chemical Group	Method	Analytical Method
Volatile Organics	Modified EPA-601, 602	GC
Base/Neutrals	EPA-625	GC/MS
Acid Extractables	EPA-604	GC
PCBs and Pesticides	EPA-608	GC
Metals	Standard Methods 15th ed.	AA

The following priority pollutant compounds were not included in these analyses: 2-chloroethyl vinyl ether, antimony, mercury, selenium, thallium, asbestos, cyanide and PCB Arochlors 1221, 1232 and 1260. Mercury was later included in the sludge study. Detailed methods are described in "Review of Analytical Methodology in Projects with New Jersey Department of Environmental Protection," Rutgers University, Department of Environmental Science, 1981, which is available from OSR.

Sludge - Priority pollutant analyses were conducted on sludge samples. The analytical methods were the same as those listed in Table 4 with two exceptions; volatile organic analysis was limited to monocyclic aromatic hydrocarbons and steam distillation was used for PCB and pesticide analysis.

Ames Testing - Ames analyses were conducted on wastewater samples collected from eight of the ten POTW facilities. Samples were prepared for Ames mutagenicity testing by a series of dechlorination (where required), filtration, resin extraction, and concentration procedures. Total residual chlorine (TRC) concentrations in the eight tested effluents ranged from 0-6.3 mg/liter, with a median value of 0.4 mg/liter. Effluent samples with TRC concentrations greater than 0.5 mg/liter were dechlorinated with ferrous ammonium sulfate. Dechlorination prevents the potential formation of additional mutagenic chlorination products, and prevents the production of low-level artifactual mutagenic activity from chlorination of the resin material used for extraction (Cheh, et al., 1980). Following dechlorination, wastewater samples were filtered through glass fiber filters. Filtered particulate matter was solvent extracted with acetone and dichloromethane.

Extraction of organics from the wastewaters was conducted with XAD-2 resin, a styrene divinylbenzene material used to adsorb relatively nonpolar organic contaminants. Extractions were performed at flow rates of 15-20 ml/minute. Desorption of contaminants was accomplished with acetone and dichloromethane washes. All resulting eluates and filter extracts were combined. Kuderna-Danish concentration was utilized to reduce the final acetone solvent volume to 2-5 ml for Ames testing. Overall sample concentrations of 2,000 to 5,000-fold were achieved. Sample extracts were gravimetrically analyzed to determine the extractable residue concentrations in the original wastewater.

During the POTW project several quality assurance samples were analyzed with the Ames test. One laboratory blank (deionized, distilled water), one field blank collected through the sampler, and two duplicate wastewater samples were assayed for mutagenic activity.

Mutagenicity analysis was conducted using the Salmonella typhimurium microsomal test. The plate incorporation method described by Maron and Ames (1983) was followed. Two bacterial tester strains, TA98 and TA100, were used. Strains were routinely checked for confirmation of genotypes. With each experiment, concurrent tests were performed for spontaneous reversion, solvent control reversion, positive control reversion, and tester strain viability. Each assay was performed with and without metabolic activation (S9). Following preliminary range-finding toxicity assays, a minimum of five doses of sample extract were tested. Duplicate plates per dose level were utilized.

Results of the Ames analyses were qualitatively categorized as positive, marginal, or negative. A positive response was defined as a two-fold or greater increase in revertants on sample plates over solvent control plates, and a clear dose-response over three or more doses. The results of an assay were classified as negative if neither of these criteria was satisfied, and marginal if only one criterion was applicable. Estimates of quantitative positive activity were derived from linear regression analyses of the initial linear portions of the dose response curves. Mutagenicity data were calculated on the basis of both revertants/ug of extracted material and revertants/equivalent milliliter of wastewater. Extractable residue concentrations were utilized to convert results expressed as revertants/ug to revertants/equivalent milliliter.

Details of the sample preparation and Ames analyses procedures described above have been presented elsewhere (McGeorge et al., 1983 and 1985). Specific protocols for both methodologies are on file with the OSR.

Fish Bioassay - The general procedures for the fish bioassay were in accordance with methods outlined in NJDEP, DWR, Bioassay Laboratory Standing Operating Procedure Manual, and the Regulations Governing Laboratory Certification and Standards of Performance (N.J.A.C. 7:18.6.0 et seq.). Replicate bioassays were conducted at each site using the following effluent-by-volume concentrations: 5.6%, 10%, 18%, 32%, 50%, 100% and a dilution water control. In addition to the static and 96-hour flow-through fish bioassay, the Biological Services Section (BSS) conducted several conventional pollutant tests (BOD, pH, etc.) on the effluents and dilution waters. These chemical analyses were performed by the New Jersey Department of Health Laboratory using Standard Methods for the Examination of Water and Wastewater, 15th edition. The results from these chemical analyses are included in part in this report. The complete analytical results are available in the BSS final bioassay reports.

Air - The OSR Mobile Monitoring Unit was utilized to study the air emissions at four of the ten facilities. Ambient air was pumped through cartridges containing Tenex GC porous polymer utilizing a Nutech Model 2221-MC AC/DC portable sampler. Final air volumes of 20 liters (0.02 cubic meters) were collected at a rate between 100-220 cubic centimeters/minute. The volatile organic compounds trapped on this absorbent were recovered by thermal desorption and helium purging into an indirectly cooled nickel capillary trap. The trap was valved into the gas chromatograph equipped with a SP-1000 Carbopak B column. Constituents were identified using a mass spectrometer that measured the intensity of the total ion current signal of mass fragmentology. Additional details regarding sampling and analytical protocol can be obtained from OSR.

VII. Results

A. Analytical Results

1. Data Presentation

Due to the extensive number of analyses conducted during this study, all of the raw priority pollutant data generated are attached in tabular form in the appendices. Appendix I lists the concentrations of the priority pollutants detected in the influent, effluent, and sludge of each individual facility. These data were reorganized in Appendix II to provide a comparison of results among the facilities tested. In Appendix II, separate tables were prepared for the influent, effluent, and sludge samples. The raw data for the follow-up sludge study are given in Appendix III. A list of compounds analyzed for, but not detected are included in Appendix IV. Those pollutants determined to be non-detectable have been indicated by blank spaces in all appendices. Summary statistics for all raw data are included in the following text.

2. Influent Wastewater Results

The total concentration and number of pollutants are given for each POTW in Table 5. The average concentration and number of detected priority pollutants are provided for all facilities. The influent wastewater samples revealed an average of 24 priority pollutants per facility at a total concentration of 3615 ug/l. A breakdown of the results shows that the volatile organic group, with an average of 11 compounds per facility, had the highest number of priority pollutants in the influent samples. The metals group, with an average concentration of 1594 ug/l per facility, had the highest concentration of priority pollutants.

Summary statistics for each detected priority pollutant compound are given in Table 6. Because an arithmetic average can be skewed by one high pollutant concentration, geometric means are also provided to give a more reliable measure of central tendency. Whenever average concentrations are discussed in the text for specific compounds, geometric means are used.

The five most frequently identified volatile organic compounds were the commonly used industrial solvents tetrachloroethylene, toluene, benzene, 1,1,1-trichloroethane, and trichloroethylene. These compounds were detected in 85% or more of the influent samples. Toluene was detected at both the highest average (85 ug/l) and maximum (5160 ug/l) concentrations of any volatile compound. Benzene, another aromatic solvent, was detected at a substantially lower average, 19.4 ug/l. It is of interest to note that although less frequently identified, the dichlorinated benzenes were found at relatively high average concentrations (16.1 to 31.2 ug/l).

Table 5. Influent Priority Pollutant Analysis
Total Concentration (ug/l)[1]/Total Number of Compounds

	Total Priority Pollutants	Volatile Organics	Base/ Neutrals	Phenols	Pesticides & PCBs	Metals
Atlantic	248/22[2]	50/9	17/3	0/0	0.3/2	181/8
Gloucester	353/17	24/5	44/4	0/0	0/9	258/8
Hightstown	415/20	197/8	109/3	0/0	1.3/5	109/4
Kearny	4956/30	509/14	3660/3	354/1	0.8/4	433/8
MCUA	12557/28	4106/13	139/2	914/1	0.5/3	7398/8
N. Arlington	678/25	410/13	98/2	0/0	0.3/3	169/7
PVSC	6758/27	2257/11	185/4	1500/2	0.9/1	2816/9
Perth Amboy	916/17	215/7	170/1	0/0	2.6/2	528/7
Rutherford	8670/25	4768/14	52/2	0/0	1.0/1	3849/8
Totowa	600/25	209/12	218/3	0/0	0.03/2	173/8
Average of All Facilities	3615/24	1275/11	469/3	276/0.4	0.8/2	1594/8

1. ug/l = micrograms per liter
2. e.g. 248/22 = total concentration of 248 ug/l for 22 compounds

Occurrence of [illegible]lority Pollutants
In POTW Influents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/1)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
VOLATILE ORGANICS (GC Method)						
Tetrachloroethylene	20	18	90	0.2 - 32.1	11.7	6.1
Toluene	20	18	90	5.6 - 5160	840	85.0
Benzene	20	17	85	3.0 - 488	82.3	19.4
1,1,1-Trichloroethane	20	17	85	1.0 - 126	32.1	12.1
Trichloroethylene	20	17	85	1.6 - 66.5	23.0	11.1
Dichlorobromomethane	20	16	80	0.1 - 5.5	1.5	1.0
Chloroform	20	15	75	14.0 - 126	16.7	5.7
Ethylbenzene	20	14	70	1.4 - 2170	309	19.2
Tetrachloroethane	20	11	55	0.1 - 35.7	7.6	6.1
Chlorodibromomethane	20	9	45	0.1 - 1.3	0.4	0.3
1,4-Dichlorobenzene	20	9	45	9.5 - 183	60.8	31.2
Carbon tetrachloride	20	7	35	0.4 - 19.7	6.2	4.3
1,2-Dichlorobenzene	20	7	35	4.8 - 98.6	35.1	20.8
1,2,4-Trichlorobenzene	20	6	30	2.9 - 51.1	17.5	12.1

Table 6 (Continued)
Occurrence of Priority Pollutants
In POTW Influents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/l)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
VOLATILE ORGANICS (Cont'd)						
1,1,2-Trichloroethane	20	5	25	0.1 - 1764	353	1.8
1,3-Dichlorobenzene	20	4	20	5.4 - 93.5	30.9	16.6
Bromoform	20	2	10	0.9 - 1.6	1.3	1.3
1,2-Dichloroethane	20	2	10	6.3 - 115	60.9	27.0
1,2-Dibromomethane	20	1	5	2.0	2.20	2.0
Dichloromethane	20	1	5	8.4	8.4	8.4
BASE/NEUTRALS						
Bis(2-ethylhexyl) phthalate	10	9	90	5.9 - 3090	376	45.3
Di-n-butyl phthalate	10	6	60	6.9 - 212	62.8	36.1
Butyl benzyl phthalate	10	5	50	5.3 - 358	115	29.2
Diethyl phthalate	10	4	40	5.9 - 132	56.1	28.0
Di-n-octyl phthalate	10	1	10	22.3	22.3	22.3
2,4-Dinitrotoluene	10	1	10	56.6	56.6	56.6

Table 6 (Continued)
Occurrence Priority Pollutants
In FoTW Influents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/l)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
BASE/NEUTRALS (Cont'd)						
Fluorene	10	1	10	18.4	18.4	18.4
Napthalene	10	1	10	40.2	40.2	40.2
PHENOLS						
Phenol	9	3	33	354 - 1500	1207	1171
2,4-Dimethylphenol	9	1	11	74.0	74.0	74.0
PESTICIDES/PCB's						
a-BHC	10	3	30	0.02 - 0.43	0.17	0.08
4,4'-DDT	10	3	30	0.01 - 0.1	0.05	0.04
g-Chlordane	10	3	30	0.06 - 0.23	0.15	0.13
Aroclor 1254	10	2	20	0.76 - 2.48	1.62	1.37
b-BHC	10	2	20	0.87 - 1.0	0.94	0.87
g-BHC (lindane)	10	2	20	0.01 - 0.89	0.45	0.09
a-Chlordane	10	2	20	0.16 - 0.23	0.20	0.19
4,4'-DDD	10	2	20	0.01 - 0.02	0.02	0.01

Table 6 (Continued)
Occurrence of Priority Pollutants
In POTW Influents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/l)	AVERAGE CONCENTRATION	
					ARITHMETIC	GEOMETRIC
PESTICIDES/PCB's (Cont'd)						
4,4'-DDE	10	1	10	0.02	0.02	0.02
Dieldrin	10	1	10	0.05	0.05	0.05
A-Endosulfan	10	1	10	0.13	0.13	0.13
Heptachlor epoxide	10	1	10	0.04	0.04	0.04
METALS						
Copper	10	10	100	30.0 - 3300	505	137
Lead	10	10	100	1.5 - 344	82.4	28.3
Zinc	10	10	100	34.0 - 6300	813	198
Arsenic	10	9	90	1.0 - 12.0	5.1	3.0
Chromium	10	9	90	2.5 - 900	138	31.1
Nickel	9	9	90	5.0 - 250	48.6	22.9
Silver	9	9	90	1.3 - 40.0	11.4	5.9
Cadmium	10	8	80	1.1 - 33.0	11.0	7.5
Beryllium	10	1	10	9.9	9.9	9.9

Ethylbenzene was detected in 70% of the samples at a maximum concentration of greater than 2000 ppb. The three most frequent occurring halogenated volatile compounds, tetrachloroethylene, 1,1,1-trichloroethane, and trichloroethylene, had average concentrations between 6.1 and 12.1 ug/l.

The influent samples contained an average of 3 base/neutral compounds per facility at a mean concentration of 469 ug/l. Bis(2-ethylhexyl) phthalate was the most frequently identified compound in the base/neutral fraction for the influent samples, as well as all other samples collected during this study. This plasticizer was detected in 90% of the influent samples at a relatively high average concentration (45.3 ug/l). The next most frequently occurring base/neutral compounds were also phthalates (di-n-butyl phthalates, butyl benzyl phthalate and diethyl phthalate). These compounds, particularly bis(2-ethylhexyl) phthalate, have been associated with laboratory contamination at low concentrations. Extensive environmental analyses conducted by the USEPA have found the phthalates to be ubiquitous, resulting from sampling, laboratory contamination, or actual presence in the environment. This information makes the interpretation of phthalate data difficult. The other base/neutral compounds detected in the influent samples were identified only once (2,4-dinitrotoluene, fluorene, and napthalene at 56.6, 18.4, and 40.2 ug/l, respectively).

The two remaining organic groups, phenols and pesticides/PCBs were less frequently detected. Individual phenolic compounds were detected only four times in all of the influent samples, but at relatively high concentrations. Phenol, which was detected in 3 of the samples, was present at concentrations ranging from 354 to 1500 ug/l. The only other compound identified in this group was 2,4-dimethylphenol, which was detected in one sample at 74 ug/l. In contrast, compounds from the pesticide/PCB group were detected more frequently, but at very low concentrations. An average of 2 compounds per sample was detected at a mean concentration of 0.8 ug/l.

The metals group had an average concentration of 1594 ug/l per facility. With the exception of beryllium, all of the metals were detected in greater than 80% of the samples. Copper and zinc, were found in every sample and were detected at the highest average concentrations (137 and 198 ug/l, respectively). While the high concentrations of copper and zinc are most likely due to industrial input, the high frequency of detection also correlates with the fact that these are naturally occurring elements which are present in relative abundance in surface and groundwater systems (Tucker, 1981).

3. Effluent Wastewater Results

The effluent wastewater analyses, presented in Table 7, indicate a decrease in both the average total concentration and number of priority pollutants from those found in the influent sample analyses. An average of 21 priority pollutant compounds were identified per sample at an average concentration of 2080 ug/l. The volatile organic group, with an average number of 9 compounds per facility, was again a major constituent of the total priority pollutant concentration (618 ug/l). The metals group, with an average concentration of 1008 ug/l per facility, accounted for the highest concentration of priority pollutants in the effluent samples.

The base/neutral group contained an average of 2 compounds per facility at an average concentration of 414 ug/l (Table 7). This represented 20% of the total concentration of priority pollutants in the effluents. Consistent with the influent analyses, bis(2-ethylhexyl) phathalate was the most frequently occurring compound in this group. This phthalate was detected in 100% of the effluent samples with a geometric mean concentration of 58.5 ug/l (Table 8). The next most frequently identifed base/neutral compounds were also phthalates. The remaining compounds in this group were not detected more than once.

Relatively few phenolic or pesticide/PCB compounds were detected in the effluent wastewater samples. Phenol was the only phenolic compound detected in the effluent. It was detected in one sample at 395 ug/l. The pesticide/PCBs group contained an average of 2 compounds per facility, at very low concentrations (Table 8). The average concentration for pesticides and PCBs observed in the effluent was only 0.5 ug/l per facility. In fact, the maximum concentration level for any compound in this group observed was only 1.67 ug/l for Aroclor 1254.

The average concentration of metals per facility was 1008 ug/l, which was nearly half of the total priority pollutant load. With the exception of beryllium, the metals were detected in more than 90% of the effluent samples. Copper, lead, nickel, and zinc were identified in 100% of the samples. Copper and zinc consistently exhibited the highest concentrations resulting in geometric means of 92.2 and 125 ug/l, respectively.

Table 7. Effluent Priority Pollutant Analysis
Total Concentration (ug/l)/Total Number of Compounds

	Total Priority Pollutants	Volatile Organics	Base/ Neutrals	Phenols	Pesticides & PCBs	Metals
Atlantic	254/15	9/5	48/2	0/0	0/0	197/8
Gloucester	86/18	17/4	20/1	0/0	0.6/6	49/7
Hightstown	517/13	21/4	348/1	0/0	0.3/2	148/6
Kearny	3851/28	300/12	2825/3	395/1	0.2/4	331/8
MCUA	3604/26	220/14	77/1	0/0	0.5/2	3307/8
N. Arlington	388/22	62/10	166/3	0/0	0.4/2	160/7
PVSC	1390/27	190/12	42/4	0/0	0.8/2	1158/9
Perth Amboy	1335/19	493/7	355/2	0/0	1.8/2	487/8
Rutherford	8965/23	4768/12	95/2	0/0	0.5/1	4102/8
Totowa	409/23	103/10	166/3	0/0	1.0/2	139/8
Average of All Facilities	2080/21	618/9	414/2	40/1	0.5/2	1008/8

Table 8
Occurrence of Priority Pollutants
In POTW Effluents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/1)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
VOLATILE ORGANICS (GC Method)						
Trichloroethylene	19	16	84	0.4 - 66.7	13.3	4.2
Tetrachloroethylene	19	15	79	1.8 - 23.4	7.8	4.8
Dichlorobromomethane	19	14	74	0.2 - 4.3	1.8	1.2
Benzene	19	13	68	1.1 - 169	100	10.4
Chloroform	19	13	68	0.9 - 47.9	10.4	4.5
Toluene	19	13	68	1.7 - 3130	436	27.6
1,1,1-Trichloroethane	19	12	63	1.5 - 7923	31.3	16.9
Chlorodibromomethane	19	11	58	0.1 - 5.7	0.9	0.4
Carbon tetrachloride	19	8	42	0.1 - 13.9	3.9	1.5
Ethylbenzene	19	8	42	3.7 - 1510	372	40.4
1,2-Dichlorobenzene	19	6	31	5.4 - 37.4	22.0	16.3
Bromoform	19	5	26	1.0 - 2.8	1.5	1.4
1,4-Dichlorobenzene	19	4	21	6.1 - 128	46.2	23.0
1,2,4-Trichlorobenzene	19	4	21	4.2 - 77.5	29.1	14.9
1,2-Dibromomethane	19	3	16	1.2 - 3.6	2.3	2.1

Occurrence of Priority Pollutants
In P[illegible] Effluents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/1)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
VOLATILE ORGANICS (Cont'd)						
1,2-Dichloroethane	19	3	16	6.2 - 72.6	34.3	22.3
1,1,2,2-Tetrachloroethane	19	3	16	0.7 - 0.8	0.7	0.7
1,3-Dichlorobenzene	19	2	11	2.2 - 24.8	13.5	7.4
Dichloromethane	19	1	5	33.9	33.9	33.9
BASE/NEUTRALS						
Bis(2-ethylhexyl) phthalate	10	10	100	8.3 - 2470	317	58.5
Butyl benzyl phthalate	10	4	40	7.0 - 274	93.1	42.9
Di-n-buytyl phthalate	10	4	40	12.1 - 81.3	36.1	27.9
Diethyl phthalate	10	3	30	3.3 - 136	51.0	18.4
Anthracene	10	1	10	29.0	29.0	29.0
2,4-Dinitrotoluene	10	1	10	47.3	47.3	47.3
Fluorene	10	1	10	16.3	16.3	16.3
Napthalene	10	1	10	16.5	16.5	16.5
Nitrobenzene	10	1	10	16.7	16.7	16.7
Phenanthrene	10	1	10	27.7	27.7	27.7

Priority Pollutants
In POTW Effluents

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/l)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
PHENOLS (acid extractables)						
Phenol	10	1	10	395	395	395
PESTICIDES/PCB's						
Y-BHC (lindane)	10	3	30	0.02 - 0.40	0.22	0.13
PCB Aroclor 1254	10	2	20	0.07 - 1.67	0.87	0.34
a-BHC	10	2	20	0.03 - 0.03	0.03	0.03
b-BHC	10	2	20	0.38 - 0.50	0.44	0.44
a-Chlordane	10	2	20	0.01 - 0.10	0.06	0.03
g-Chlordane	10	2	20	0.01 - 0.19	0.10	0.04
4,4'-DDT	10	2	20	0.06 - 0.08	0.07	0.07
a-Endosulfan	10	2	20	0.03 - 0.12	0.08	0.06
Heptachlor epoxide	10	2	20	0.02 - 0.29	0.16	0.08
4,4'-DDE	10	1	10	0.02	0.02	0.02
Dieldrin	10	1	10	0.46	0.46	0.46
Heptachlor	10	1	10	0.97	0.97	0.97

Table 8 (Continued)
Occurrence of Priority Pollutants
In POTW Effluents

METALS	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (ug/l)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
Copper	10	10	100	10.0 - 3575	493	92.2
Lead	10	10	100	1.7 - 400	51.1	10.2
Nickel	10	10	100	10.0 - 70.0	28.2	23.0
Zinc	10	10	100	10.0 - 3650	415	125
Arsenic	10	9	90	0.9 - 13.3	4.4	2.4
Cadmium	10	9	90	1.0 - 21.0	7.5	4.2
Chromium	10	9	90	3.0 - 165	48.6	20.7
Silver	10	9	90	1.0 - 35.0	7.9	4.5
Beryllium	10	1	10	3.1	3.1	3.1

4. Sludge Results

a. POTW Study

The analytical results for the sludge samples, presented in Table 9, show much higher concentrations of priority pollutants on a per volume basis than either the influent or effluent wastewater samples. Average sludge concentrations of these pollutants were more than three orders of magnitude above the treated and untreated wastewater samples. An average of 5323 mg/kg (dry weight) of these toxic pollutants were present in this sample matrix as opposed to 3.5 and 2.1 mg/kg respectively for the influent and effluent wastewater samples. This can be attributed to the increased solids content of the sludge which in turn concentrates any pollutants adsorbed to the solids.

The metals account for 88% of the priority pollutant concentration (4665 mg/kg). There were no phenolic compounds detected. Base/neutrals and the monocyclic aromatic volatiles were detected at an average of 558 mg/kg and 78 mg/kg, respectively. The average observed concentration of pesticide/PCBs was 3.8 mg/kg. Although the concentration of priority pollutants was higher, the average number of compounds detected in the sludge samples was only 17 compared to 24 in the influent and 21 in the effluent. This is due in part to the fact that the sludge analyses was limited to monocyclic aromatic hydrocarbons, rather than the entire volatile scan performed on the wastewater samples. The three volatile organic priority pollutants detected with this group are benzene, ethylbenzene and toluene. Benzene and toluene were detected in all of the sludge samples at geometric means of 5.5 and 8.8 mg/kg. Ethylbenzene was observed in 82% of the samples at a mean of 8.8 mg/kg (Table 10).

The plasticizer, bis(2-ethylhexyl) phthalate was detected in every sludge sample. The geometric mean was 172 mg/kg. Butybenzyl phthalate and di-n-butyl phthalate were detected in 27% of the samples. The eight other base/neutral compounds were identified in only one or two of the sludge samples.

A total of 11 different pesticide/PCBs were detected in the sludge samples. Although these compounds were detected infrequently, they were present at higher concentrations than in the wastewater samples. This can be attributed to the increased solids content of this matrix and the hydrophobic nature of these compounds.

Table 9. Sludge Priority Pollutant Analysis
Total Concentration (mg/kg)*/Total Number of Compounds

	Volatile Organics	Base/ Neutrals	Phenols	Pesticides & PCBs	Metals	Total Priority Pollutants
Atlantic	3/3	52/1	0/0	0.1/2	3314/9	3481/15
Gloucester	3/2	100/1	0/0	1.5/4	2764/9	4409/16
Hightstown	177/3	97/1	0/0	1.7/1	3438/8	5381/13
Kearny	11/3	2265/5	0/0	0/0	237/8	2513/16
MCUA	16/3	1760/1	0/0	3.5/2	18525/8	23765/14
N. Arlington	280/3	90/2	0/0	0.1/1	2230/9	2727/15
PVSC	6/3	94/3	0/0	0.5/3	5005/8	5105/17
Perth Amboy	8/3	568/10	0/0	0.2/1	4710/8	5286/22
Rutherford	105/3	710/2	0/0	15.9/2	4273/9	5104/16
Totowa	46/3	147/1	0/0	14.9/3	2154/8	2362/15
Average of All Facilities	66/3	588/3	NA	3.8/2	4665/8	5323/16

NA - Not Applicable

* mg/kg = milligrams per kilogram

Table 10
Occurrence of Priority Pollutants
In POTW Sludges

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (mg/kg)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
VOLATILE ORGANICS (GC Method)						
Benzene	11	11	100	1.3 - 31.2	10.3	5.5
Toluene	11	11	100	0.8 - 219	42.2	8.8
Ethylbenzene	11	9	82	0.7 - 42.2	11.2	8.8
BASE/NEUTRALS						
Bis(2-ethylhexyl) phthalate	11	11	100	37.6 - 1760	438	172
Butylbenzyl phthalate	11	3	27	101 - 185	153	148
Di-n-butyl phthalate	11	3	27	17.7 - 266	105	52.0
Anthrancene	11	2	18	32.2 - 50.0	41.1	40.1
Phenanthrene	11	2	18	32.7 - 47.6	40.2	39.5
1,2,4-Trichlorobenzene	11	2	18	16.0 - 52.2	34.1	28.9
2,4-Dinitrotoluene	11	1	9	41.4	41.4	41.4
Fluoranthrene	11	1	9	28.6	28.6	28.6
Fluorene	11	1	9	39.4	39.4	39.4
Napthalene	11	1	9	13.6	13.6	13.6

Table 10 (Continued)
Occurrence of Priority Pollutants
In POTW Sludges

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (mg/kg)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
BASE/NEUTRALS (Con't)						
Pyrene	11	1	9	24.6	24.6	24.6
PHENOLS (none detected)						
PESTICIDES/PCBs				(ug/kg)		
a-Chlordane	11	3	27	55.0 - 860	542	323
g-Chlordane	11	3	27	71.8 - 809	353	218
Aldrin	11	2	18	633 - 9280	496	2414
Aroclor 1242	11	2	18	77.9 - 5130	2604	632
b-BHC	11	2	18	94.3 - 6600	3347	789
4,4'-DDD	11	2	18	29.3 - 56.9	43.1	40.8
Dieldrin	11	2	18	11.4 - 371	191	65.0
Aroclor 1016	11	1	9	3370	3370	3370
Aroclor 1254	11	1	9	186	186	186
a-BHC	11	1	9	153	153	153
g-BHC (Lindane)	11	1	9	10.4	10.4	10.4

Table 10 (Continued)
Occurrence of ority Pollutants
In POTw Sludges

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (mg/kg)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
PESTICIDES/PCBs (Con't)				(ug/kg)		
a-endosulfan	11	1	9	104	104	104
Heptachlor	11	1	9	382	382	382
Heptachlor epoxide	11	1	9	9800	9800	9800
METALS				(mg/kg)		
Arsenic	11	11	100	1.8 - 58.8	13.5	8.2
Cadmium	11	11	100	3.0 - 85.3	33.3	20.4
Chromium	11	11	100	11.0 - 1244	417	135
Copper	11	11	100	86.1 - 3794	796	575
Nickel	11	11	100	12.0 - 143	63.5	44.4
Silver	11	11	100	1.0 - 1170	189	26.4
Zinc	11	11	100	87.0 - 11,559	2012	942
Beryllium	11	5	45	3.0 - 85.3	33.3	20.4

All of the metals, except beryllium, were detected in 100% of the sludge samples. Arsenic had the lowest geometric mean of 8.2 mg/kg, and copper and zinc had the highest, with 575 mg/kg and 942 mg/kg, respectively.

b. Sludge Study

The analytical results from the sludge study, presented in Table 11, are similar to the POTW sludge results described in the preceding section. The average concentration of priority pollutants for the 12 plants tested was 7809 mg/kg.

The most frequently occurring group of compounds in the sludge study were the metals. Every metal analyzed was detected in 100% of the samples (Table 12). Copper and zinc had the highest geometric means, 1265 and 2296 mg/kg, respectively. Chromium (187 mg/kg) and lead (428 mg/kg), two of the more toxic elements, had high geometric means compared to the remaining metals.

The most frequently occurring organic compound was bis(2-ethylhexyl) phthalate. This compound was detected in 97% of the samples at a geometric mean of 240 mg/kg. Two other phthalates, butyl benzyl phthalate and di-n-butyl phthalate, were detected less frequently with means of 108 and 102 mg/kg, respectively.

The monocyclic aromatic hydrocarbons, benzene, toluene, and ethylbenzene, were detected in 64 - 92% of the samples. Toluene had the highest mean concentration in this group, 12.5 mg/kg.

Pesticide/PCBs were generally detected at lower levels than other organic compounds. This is primarily due to the increased senstivitiy of the electron capture detector used for this methodology. Three constituents of technical grade chlordane, heptachlor epoxide, and the alpha and gamma isomers of chlordane were among the most frequently detected pesticides, in addition to beta and gamma BHC.

c. Non-Priority Pollutants

The analysis of the base/neutral fraction was performed by GC/MS. In addition to the positive identification of priority pollutants, this analytical method can also isolate additional compounds and produce a mass spectra from which, in some cases, a tentative identification can be made. Evaluations of non-priority pollutants are important because EPA estimates that for every kilogram of priority pollutants, 2.5 kilograms of non-priority pollutants are discharged to POTWs (USEPA, 1986). The laboratory was instructed to identify as many compounds

Priority Pollutant Analyses
Total Avg. Conc. (mg/kg)/Avg. Number of Compounds

	Total Priority Pollutants	Monocyclic Aromatics	Base/ Neutrals	Phenols	Pesticides/ PCBs	Metals
Atlantic	1774/19	18/2	132/2	0	1.5/5	1625/10
Bergen	8824/17	18/3	254/1	0	1.3/1	8551/10
Bayshore	3293/17	16/2	80/1	0	2.0/4	3194/10
Essex-Union	8172/15	26/2	280/1	0	1.8/3	7864/10
E. Windsor	2777/16	1/1	98/1	0	2.0/4	2676/10
Kearny	12432/	32/2	3150/4	0	0.3/2	9249/10
Linden-Roselle	18632/18	2768/2	598/1	0	12.6/4	15253/10
MCUA	11640/15	78/2	919/2	0	7.0/1	10636/10
Perth Amboy	5850/18	7/3	190/3	0	0.7/3	5656/10
PVSC	5819/15	15/3	111/1	68/1	91/2	6232/10
Rutherford	10993/17	28/3	2140/1	0	111/4	8816/10
Rahway	3500/16	630/3	676/2	0	191/1	2003/10
Average of All Facilities	7809/17	303/2	719/2	NA	42/3	6812/10

Table 12
Occurrence of Priority Pollutants
In The Sludge Study

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (mg/kg)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
VOLATILE ORGANICS (GC Method)						
Benzene	39	36	92	0.3 - 281	22.3	7.1
Toluene	39	32	82	0.3 - 6610	278	12.5
Ethylbenzene	39	25	64	0.2 - 535	39.8	7.1
BASE/NEUTRALS						
Bis(2-ethylhexyl) phthalate	39	38	97	48.1 - 5720	588	240
Butyl benzyl phthalate	39	9	23	1.2 - 658	296	108
Di-n-butyl phthalate	39	7	18	0.5 - 529	200	102
Diethyl phthalate	39	3	8	10.4 - 97.4	65.4	14.8
Anthracene	39	2	5	34.4 - 80.1	57.3	52.5
Dichlorobenzene	39	2	5	157 - 578	367	301
Phenanthrene	39	2	5	32.0 - 74.4	53.2	48.8
1,2,4-Trichlorobenzene	39	1	3	11.1	11.1	11.1
PHENOLS						
Phenol	39	4	10	16.1 - 299	133	81.2

Table 12 (Continued)
Occurrence of Priority Pollutants
In The Sludge Study

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
PESTICIDES/PCBs				(ug/kg)		
b-BHC	39	23	59	75.80 - 13,400	1423	245
g-Chlordane	39	13	33	75.20 - 3,820	1100	558
g-BHC (lindane)	39	12	31	12.40 - 19,300	2080	282
a-Chlordane	39	12	31	85.70 - 5,120	1373	661
Heptachlor expoxide	39	11	28	15.00 - 9,800	1556	296
4,4'-DDE	39	9	23	13.10 - 1360	722	763
Aldrin	39	6	15	1.27 - 1,440	1140	41.5
4,4'-DDD	39	4	10	45.90 - 212	115	24.7
Heptachlor	39	4	10	49.40 - 2,300	476	150
a-BHC	39	3	8	5.03 - 27.60	18.6	14.7
4,4'-DDT	39	3	8	21.30 - 558	138	112
Dieldrin	39	3	8	54.10 - 381	202	163
Endosulfan	39	1	3	285	285	285
Mirex	39	1	3	1,000	1,000	1,000
METALS				(mg/kg)		
Arsenic	39	39	100	1.1 - 199	29.8	10.4

Table 1 Continued)
Occurrence of Priority Pollutants
In The Sludge Study

	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (mg/kg)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
METALS (Con't)						
Beryllium	39	39	100	0.17 - 3.56	0.7	0.5
Cadmium	39	39	100	1.85 - 563	76.3	24.9
Chromium	39	39	100	6.5 - 10,142	739	187
Copper	39	39	100	224 - 5,385	1749	1265
Lead	39	39	100	49.2 - 4,730	796	428
Mercury	39	39	100	0.9 - 282	23.1	7.2
Nickel	39	39	100	8.8 - 2,047	909	208
Silver	39	39	100	2.58 - 240	70.6	35.0
Zinc	39	39	100	317 - 13,377	3495	2296

in each sludge sample as possible, particularly those "unknowns" producing the largest peaks on the chromatograph.

Most of the sludge samples contained numerous aliphatic and unsaturated hydrocarbons. Other common substances were various naphthalenes and benzenes with alkyl substitutions. There were occasional occurrences of chlorinated aromatic compounds such as chlorotoluene and trichloromethylbenzene. Cyclic nitrogen-containing compounds including indole and imidazole were present in several samples, as were some substituted indenes. In addition to the above compounds and chemical groups, most sludges contained other substances that could not be identified. It should be noted that because no standards were obtained for these compounds, they could not be verified or quantified. A complete listing of these additional sludge pollutants, by facility, is available from the Office of Science and Research.

Volatile organic compounds in the sludge samples were analyzed utilizing a GC monocyclic aromatic method, and cumene, meta-, ortho-, and para-xylene were routinely detected with this method. The results for these four non-priority pollutants are in Table 13. Generally, these compounds were detected frequently in the sludge samples, at relatively low concentrations.

B. Biological Monitoring Results

1. Ames Test Results

Preliminary toxicity tests of the POTW extracts were conducted to determine dose levels for subsequent mutagenicity analyses. These range-finding assays revealed cytotoxicity at doses generally lower than previously observed for industrial wastewater extracts. Such cytotoxicity was evident by the reduction in the background lawn of bacteria as observed in a dissecting microscope. Strain TA 100 was the most sensitive to the toxic effects. Toxicity was detected more frequently without metabolic activation than with S-9. The significance of the more pronounced POTW extract toxicity was that some low levels of mutagenic activity may not have been detectable because it was necessary to test certain samples at lower doses than had previously been used for industrial wastewaters. Cytotoxicity of POTW wastewater extracts at relatively low doses has previously been reported by other investigators (Meier and Bishop, 1985).

The qualitative results of the mutagenicity analyses are presented in Table 14. The data show that among the eight facilities tested, the majority of the Ames results were negative for both influent and effluent samples. Of the eight tested influents, only the Atlantic County facility

Table 13
Non-Priority Pollutant Volatile Organic Compounds in Sludges

COMPOUND	NUMBER OF TIMES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT DETECTED	CONCENTRATION RANGE (mg/kg)	AVERAGE CONCENTRATION ARITHMETIC	AVERAGE CONCENTRATION GEOMETRIC
		Sludge Study 1st Sampling				
Cumene	13	10	77	2.2 - 38.6	13.6	8.5
m-xylene	13	1	8	0.3	0.3	0.3
o-xylene	13	5	38	0.3 - 52.5	15.5	5.1
p-xylene	13	6	46	0.6 - 101	27.7	7.8
		Sludge Study 2nd Sampling				
Cumene	13	6	46	5.0 - 164	35.3	13.9
m-xylene	13	9	69	1.2 - 32.3	6.7	3.5
o-xylene	13	9	69	0.8 - 461	58.5	8.5
p-xylene	13	11	85	1.9 - 955	104	14.9
		Sludge Study 3rd Sampling				
Cumene	13	7	54	0.6 - 281	49.9	13.0
m-xylene	13	9	69	0.4 - 26.7	6.0	3.0
o-xylene	13	10	77	0.2 - 697	75.3	4.2
p-xylene	13	10	77	0.7 - 1440	156	10.1
		POTW Sludge Samples				
Cumene	11	10	91	1.7 - 39.5	17.2	11.0
m-xylene	11	5	46	1.2 - 13.3	6.9	4.2
o-xylene	11	11	100	1.1 - 52.5	12.7	6.0
p-xylene	11	11	100	0.3 - 46.6	9.6	4.0

Table 14: Qualitative Ames Mutagenicity Assay Results[1]

Facility	Influent	Effluent
Atlantic County	(+/-)	(+/-)
Hightstown	(-)	(+),(+)[2]
Kearny	(-,)(-)[2]	(-)
N. Arlington-Lyndhurst	(-)	(-)
Passaic Valley	(+)	(+)
Perth Amboy	(-)	(-)
Rutherford	(-)	(-)
Totowa	(-)	(-)

[1] (-) = Negative, (+/-) = Marginal, (+) = Positive
[2] Duplicate results

produced marginal results, and the Passaic Valley plant was positive. Of the eight tested effluents in the Ames assay, Hightstown and Passaic Valley, were positive and one, Atlantic County was marginal. Quality assurance duplicate samples produced consistent Ames responses; both Kearny influent samples were negative and the two Hightstown effluents were positive. Lab blank and field blank samples were negative in the Ames test.

The strain-specific responses for the positive wastewater extracts are summarized in Table 15. The mutagenic activity detected in the positive POTW samples was observed for both tester strains TA98 and TA100. In addition, some response was observed for these positive extracts when assayed without as well as with metabolic activation. Such variation in response types implies that a mixture of a number of active components was responsible for the detected mutagenic activity. The wastewater extracts from the Atlantic County facility produced marginal responses with strain TA98 without S-9 only.

2. Fish Bioassay Results

Fish bioassay studies were conducted by DWR personnel at three of the ten POTWs tested for this study. Replicate bioassays were conducted at each site using the following Summaries of the tests results provided by the participating bioassay personnel are as follows:

- Hightstown Borough STP

The estimated median lethal concentration (LC_{50}) for the Hightstown effluent was greater than 100% effluent-by-volume. No tested concentration exhibited more than a 10% response. Lead and chromium values exceeded the criteria for freshwater aquatic life on at least one occasion. Table 16 shows the bioassay results and BOD, COD, and TOC values for the effluent over the four day test period.

- N. Arlington/Lyndhurst STP

The LC_{50} for this facility was 20.5% effluent-by-volume. There was total response (100% mortality) in all concentrations down to and including 32% effluent-by-volume by the end of the 96 hours. At the end of 24 hours there was complete mortality in the 100% and 56% effluent-by-volume. An evaluation of the effluent and dilution water chemical analyses indicate acutely toxic levels of un-ionized ammonia in all of the effluent dilutions on at least one day during the test period. The effluent BOD, COD and TOC analytical results reported in Table 16, indicate a substantial organic loading which may have contributed to organism mortality.

- Totowa West End STP

Table 15. Ames Mutagenicity Results for Positive Wastewater Extracts

Facility/Sample	Strain			
	Without S9		With S9	
	TA98	TA100	TA98	TA100
A. Revertants/mg				
Passaic Valley/Influent	55	(-)[1]	56	(-)
Passaic Valley/Effluent	110	240	100	(-)
Hightstown/Effluent[2]	89	240	(-)	(+/-)
B. Revertants/liter				
Passaic Valley/Influent	2990	(-)	3040	(-)
Passaic Valley/Effluent	1840	3900	1690	(-)
Hightstown/Effluent[2]	630	1700	(-)	(+/-)

1 (-) negative; (+/-) marginal
2 Hightstown results represent the average of data from two duplicate samples

Table 16

Fish Bioassasy and Selected Analytical Results

Hightstown - LC_{50} 100%

DATE	BOD (mg/l)	COD (mg/l)	TOC (mg/l)	Other Perinent Analysis Cr(ug/l)	Pb(ug/l)
6/20	20	69	28	<5	20
6/21	12	59	26	<5	210*
6/22	17	27	28	201*	14
6/23	16	43	23	<5	16

* Values Exceeding New Jersey Surface Water Quality Standards

N. Arlington/Lyndhurst - LC_{50} 20.5%

DATE	BOD (mg/l)	COD (mg/l)	TOC (mg/l)	Other Pertinent Analysis Un-ionized Ammonia (mg/l)
5/16	278	436	161	0.035*
5/17	228	297	169	0.301*
5/18	183	393	122	0.198*
5/19	251	268	92	0.406*

* Exceeded Criteria Developed by the USEPA (1976) and McKee and Wolf (1963)

Totowa West End STP - LC_{50} 23.7%

DATE	COD (mg/l)	TOC (mg/l)	Other Pertinent Analysis
4/18	238	69	Temperature Elevation
4/19	269	84	Depressed Dissolved
4/20	165	59	Oxygen Levels*
4/21	372	88	

* Did Not Meet NJDEP, DWR Bioassay Laboratory Standard Operating Procedure Manual Requirements

The LC_{50} for the Totowa STP was 23.7% effluent-by-volume. There was total response (complete mortality) in all concentrations down to and including the 56% effluent-by-volume at the end of 24 hours. Chemical analysis of the effluent showed no significant levels of specific toxic materials; (Table 16). It should be noted, due to variable weather conditions, temperature and dissolved oxygen requirements could not be maintained according to quality control standards.

An acceptable result for the bioassay test is minimum LC_{50} of 50% for all direct discharges as mandated by the NJ Surface Water Quality Standards. Two of the three facilities tested here failed to meet this requirement.

Some relationship may exist between reported percent industrial contribution and effluent fish bioassay results, although the number of facilities was very limited. Toxicity appears to increase as percent industrial flow increases. Also there was no apparent correlation with total effluent priority pollutants measured and the LC_{50} calculated for the three facilities (Table 17).

Table 17

Plant	LC_{50}	%Industrial Flow	Total Effluent Priority Pollutant Conc.
Hightstown	100%	5	464 ug/l
N. Arlington	20.5%	15	878 ug/l
Totowa	23.7%	25	442 ug/l

C. Air Sampling Results

The OSR Mobile Monitoring Unit (MMU) was utilized to study the air emissions at four of the ten POTW facilities. These sites were Middlesex County Utilities Authority (MCUA), Kearny Sewage Treatment Plant, Hightstown Sewage Treatment Plant, and the Rutherford Joint-Meeting Treatment Plant. Ambient air collected near the influent wastewater sampling sites, was analyzed for the presence of volatile organic compounds (VOC). The highest levels of VOC's were detected above the pre-grit chambers or where the influent of the treatment plant experienced the greatest turbulence or aeration. Where problems with worker exposure had been reported or suspected, it was decided that two additional samples would be collected. These sites were enclosed influent work areas.

The air sampling analytical results, listed in Table 18, are reported in parts per billion concentrations. Many of the compounds detected are common air pollutants in industrialized areas. These include some components of gasoline and common industrial solvents. As would be expected, POTW wastewater analyses also indicate the presence of these same volatile organic compounds. Table 18 indicates a good relationship between the compounds identified in the air samples and the wastewater samples. Only two compounds, chloroform and 1,1,2-trichloroethane, were detected in an air sample and not in the corresponding wastewater.

Although the size and quantity of samples completed for this study were limited, the results indicate that volatile organic compounds are being released into the atmosphere from the treatment of POTW wastewaters. Volatilization may account, at least in part, for the reduction of these types of compounds in sewage treatment systems.

Table 18

Comparison of Air Sampling ılytical Results with Wastewater

PLANT	COMPOUNDS DETECTED	Air Conc. ppb indoor near influent	Air Conc. ppb outside near influent	Wastewater ug/l inf.	Wastewater ug/l eff.
Kearny	t-Dichloroethylene	2.4		NA	NA
	1,1,2-Trichloroethane	1.2		ND	ND
	trichloroethylene	1.0	T		61.7
	Benzene	0.4	T	4/3	1.1
	Tetrachloroethylene	1.4		24.7	19.8
	Toluene	0.3		25.6	11.3
	Chlorobenzene	0.3	T	NA	NA
	Ethylbenzene	NS		5.1	3
Rutherford	Benzene	28.1	2.7	129	150
	Chloroform	34.4	ND	ND	ND
	Ethylbenzene	43.5	30.5	2170	1510
	Methylene chloride	24.8	0.8	NA	NA
	Methyl isobutyl ketone*	42.8	9.8	NA	NA
	1,1,1-Trichloroethane	50.5	2.0	13.3	9.2
	1,1,2-Trichloroethane	50.5	2.0	ND	ND
	Trichloroethylene	16.8	0.6	7.7	7.4
	Tetrachloroethylene	17.8	1.8	20.1	7.5
	Toluene	3000	27.1	2830	1480
MCUA	Methylene chloride		NS	NA	NA
	Chloroform		T	35	47.9
	Methyl ethyl ketone*		NS	NA	NA
	Carbon Tetrachloride		NS	7.2	4.9
	Trichloroethylene		T	35.9	10
	Benzene		2.1	488	17.1
	Hexane*		NS	NA	NA
	Toluene		4.9	3080	4.0
	Tetrachloroethylene		T	15	13

Table 18 (continued)
Comparison of Air Sampling Analytical Results with Wastewater

PLANT	COMPOUNDS DETECTED	Air Conc.ppb indoor near influent	Wastewater ug/l inf.	eff.
Hightstown STP	Methylene chloride	4.5	NA	NA
	t-1,2-Dichloroethylene	0.9	NA	NA
	Chloroform	NS	2.9	ND
	Trichloroethylene	2.0	65.4	ND
	Benzene	0.5	4.1	6.3
	Tetrachloroethylene	16.6	25.3	ND
	Toluene	7.5	18.8	1.7

T - Trace, unquantifiable
NS - No standard available for quantification
NA - Not analyzed
ND - Not detected
* - Non-priority pollutant

V. Discussion of Priority Pollutants Results

A. POTW Removal Efficiency of Priority Pollutants

Although the sample size is small, a comparison of the influent and effluent wastewater analyses reveals some trends in the removal of priority pollutants during wastewater treatment. The percent removal efficiency achieved by the primary and secondary treatment facilities for each of the chemical groups is presented in Table 19. Any net increase values calculated for individual plants were not utilized in the average percent reduction calculations.

An overall reduction of priority pollutants was observed at the facilities. The average percent removal efficiencies for all of the plants ranged from 36% reduction of base/neutrals to 100% reduction of phenols. The volatile organics and metals were reduced an average of 55% and 42%, respectively. Although the pesticide and PCB removal efficiencies are included in Table 19, the validity of the calculated removals is questionable due to the extremely low concentrations of these detected compounds.

In general, facilities with secondary treatment achieved higher rates of removal than the primary facilities. The volatile organic data illustrates this point. Secondary facilities achieved an average 83% reduction, while primary facilities only reduced volatile compounds an average of 27%.

The increased removal efficiency for volatile compounds at secondary facilities can be partially attributed to wastewater aeration and subsequent compound volatilization. Secondary facilities also showed efficient removal of compounds in the base/neutral group, 49% versus 29% removal achieved at primary plants. The same was observed in the metals group, where secondary facilities removed 72% compared to only 12% at primary plants. The increased removal efficiency of base/neutrals and metals at secondary treatment facilities can be partially attributed to improved solids removal. These compounds attach to the solid particles in the wastewater and settle out in the sludge. (Chapman, 1982) Phenolic compounds were detected at three different POTWs. Two secondary facilities achieved complete reduction, while a net increase in concentration was measured at one primary plant. Phenol is biodegradable and therefore, treatable in most sewage treatment systems (EPA, 1982). EPA has estimated that a fully acclimated secondary plant would remove 92% of all priority pollutants; 14% by air stripping, 16% to sludge, 62% being biodegraded and 8% passing through. EPA has also estimated the removal processes at an unacclimated plant. In this scenario 83% of all pollutants would be removed; 25% by air stripping, 14% to sludge, 42% being biodegraded; and 18% passing through (USEPA, 1986). While we did not observe the same removal efficiencies, it is assumed that the physical processes described by EPA are also responsible for the priority pollutant reductions at these plants.

Table 19. Percent Removal Efficiency of Priority Pollutants

PRIMARY TREATMENT FACILITIES	VOLATILE[1] ORGANICS	BASE/ NEUTRALS	PHENOLS	PESTICIDES/ PCBs	METALS
Kearny	37[2]	23	*	82	24
N. Arlington	*	*	ND	*	5
Perth Amboy	12	*	ND	*	8
Rutherford	31	34	ND	50	*
AVERAGE REDUCTION	27%	29%	NA	66%	12%
SECONDARY TREATMENT FACILITIES					
Atlantic County	81	*	ND	100	*
Gloucester County	82	51	ND	*	83
Hightstown Boro	87	*	ND	78	*
Middlesex County	95	45	100	*	55
Passaic County	91	77	100	12	59
Totowa	64	24	ND	*	20
AVERAGE REDUCTION	83%	49%	100%	63%	72%
AVERAGE REDUCTION FOR ALL FACILITIES	55%	36%	100%	64%	42%

* - net increase measured
ND - not detected in either influent or effluent samples
NA - not applicable

Footnotes
1. Percent removal was averaged from 1st and 2nd day sampling results.
2. Average percent reduction was calculated using positive reduction figures, net increase values were not included.

PLANT 4 KEARNY MUNICIPAL STP

	COMPOUND	INFLUENT ug/l DAY 1	INFLUENT ug/l DAY 2	EFFLUENT ug/l DAY 1	EFFLUENT ug/l DAY 2	SLUDGE mg/kg	INFLUENT BEFORE LIFT PUMP ug/l	SEGRAGATED INDUSTRIAL INFLUENT ug/l
Volatile Organics	Benzene	3.4	3.0	3.0	1.1	2.4	4.0	4.0
	Bromoform			1.0				
	Carbon tetrachloride		2.5	0.1				0.2
	Chlorodibromomethane		0.2	0.1				
	Chloroform	0.6	3.3	2.8	3.3		3.0	7.6
	Cumene	29.0				10.4	54.4	96.4
	1,2-Dibromoethane							0.1
	Dichlorobromomethane	0.4	0.6	2.1	1.4		0.7	0.2
	1,2-Dichlorobenzene				37.4			
	1,3-Dichlorobenzene	5.4	15.0					4.6
	1,4-Dichlorobenzene	56.6	183	42.2	128			428
	1,2-Dichloroethane							39.8
	Ethylbenzene	1.4	1.8	3.7		2.2	5.1	31.2
	1,1,2,2-Tetrachloroethane	10.0	0.6		0.7			0.3
	Tetrachloroethylene	7.9	21.8	16.1	23.4		24.7	0.8
	Toluene	19.7	19.6	17.4	5.2	5.7	25.6	38.0
	1,2,4-Trichlorobenzene		11.7					
	1,1,1-Trichloroethane	36.6	37.4	41.5	28.3			
	1,1,2-Trichloroethane	0.9	0.8					
	Trichloroethylene	33.2	58.0	66.7	56.7		69.0	0.4
	m-Xylene	5.2	8.3	4.1	2.9	1.2	10.9	2.3
	o-Xylene	68.1	20.4	52.0	35.6	4.0	13	634
	p-Xylene	13.2	9.2	11.7		3.7	14.6	
Base/Neutrals	Anthracene					32.2	NS	
	Bis (2-ethylhexyl) phthalate	3090		2470		1760	NS	3730
	Butyl benzyl phthalate	358		274		174	NS	391
	Di-n-butyl phthalate	212		81.3		266	NS	
	Pyrene					32.7	NS	
Phenols	Phenol	354		395			NS	281
Pesticides/PCBs	Aroclor 1254	0.8		0.1			NS	
	4,4'-DDD	0.01					NS	
	4,4'-DDE			0.02			NS	
	2,4'-DDT	0.1		0.1			NS	

PLANT 4 KEARNY MUNICIPAL STP (Continued)

	COMPOUND	INFLUENT ug/l	EFFLUENT ug/l	INFLUENT SLUDGE mg/kg	SEGRAGATED BEFORE LIFT PUMP ug/l	INDUSTRIAL INFLUENT ug/l
Metals	Arsenic	12	10	25.2	NS	2
	Beryllium			16.1	NS	
	Cadmium	8	7	11	NS	3
	Chromium	60	37	7452	NS	11
	Copper	135	125	223	NS	120
	Lead	30	4.2	970	NS	1
	Nickel	24	32	3132	NS	12
	Silver	2	2.0	23	NS	1
	Zinc	162	11.4	10903	NS	87
TOC		2.5 mg/l	180 mg/l		NS	760

NS - Not Sampled

INFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
VOLATILE ORGANICS ug/L					
Benzene		5.30	16.0	3.20	414
Bromoform					0.46
Carbon Tetrachloride				1.30	7.20
Chlorodibromomethane	0.12			0.12	0.40
Chloroform	1.80		1.40	2.00	28.2
Cumene	7.80	4.00	2.90	14.5	
1,2-Dibromomethane					0.98
Dichlorobromomethane	0.46		0.35	0.48	4.10
1,2-Dichlorobenzene	2.74		13.6		7.20
1,3-Dichlorobenzene				10.2	
1,4-Dichlorobenzene			7.50	120	85.4
1,2-Dichloroethane					
Ethylbenzene	1.40		2.80	1.60	12.2
1,1,2,2-Tetrachloroethane	15.4			5.30	0.57
Tetrachloroethylene	4.00	6.90	12.9	4.80	15.4
Toluene	4.90	4.80	12.2	19.6	2870
1,2,4-Trichlorobezene				5.90	11.6

INFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
BASE/NEUTRALS ug/L					
Benzo(g,h,i)perylene					
Benzo(a)pyrene					
Bis(2-chloroethoxy)methane					
Bis(2-chloroethyl)ether					
Bis(2-chloroisopropyl)ether					
Bis(2-ethylhexyl)phalate	5.90	17.1	87.0	3090	
4-Bromophenyl phenyl ether					
Butyl benzyl phalate	5.30	10.9		358	101
'2-Chloronaphthalene					
4-Chlorophenyl phenyl ether					
Chrysene					
Di-n-butyl phthalate		6.90		212	38.9
Di-n-octyl phthalate			22.3		
Dibenzo(a,h)anthracene					
1,2-Dichlorobezene					
1,3-Dichlorobezene					
1,4-Dichlorobezene					

INFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
BASE/NEUTRALS ug/L					
Nitrobenzene					
Phenanthrene					
Pyrene					
1,2,4-Trichlorobenzene					
PHENOLS ug/L					
2-Chlorophenol					
2,4-Dichlorophenol					
2,4-Dimethylphenol					
4,6-Dinitrol-o-cresol					
2,4-Dinitrphenol					
2-Nitrophenol					
4-Nitrophenol					
p-Chloro-m-cresol					
Pentachlorophenol					
Phenol				354	914
2,4,6-Trichlorophenol					

INFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
PESTICIDES/PCBs ug/L					
Aldrin					
Aroclor 1242					
Aroclor 1016					
Aroclor 1221					
Aroclor 1232					
Aroclor 1248					
Aroclor 1254				0.76	
Aroclor 1260					
a-BHC					0.43
B-BHC			0.87		
Y-BHC (lindane)					
a-Chlordane	0.23		0.16		
g-Chlordane	0.06		0.23		
4,4'-DDD			0.02	0.01	
4,4'-DDE			0.02		0.00
4,4'-DDT	0.01			0.05	
Dieldrin					0.05

INFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
PESTICIDES/PCBs ug/L					
a-Endosulfan					
B-Endosulfan					
Endosulfan sulfate					
Endrin					
Endrin aldehyde					
Heptachlor					
Heptachlor epoxide			0.04		
Methoxychlor					
Mirex					
Toxaphene					
METALS ug/L					
Arsenic	1.30	1.10	0.00	12.0	10.0
Beryllium	0.00	0.00	0.00	0.00	0.00
Cadmium	2.10	2.20	0.00	8.00	29.0
Chromium	2.50	15.0	0.00	60.0	55.0
Copper	40.0	60.0	63.0	135	645

INFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
METALS ug/L					
Lead	16.8	52.0	1.50	30.0	300
Nickel	5.00	20.0	10.0	24.0	31.0
Silver	3.00	1.25	0.00	2.00	28.0
Zinc	110	133	34.0	162	6300
TOC (mg/l)	85.0	40.0	49.0	245	280

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
VOLATILE ORGANICS ug/L					
Benzene		2.60	14.5	2.05	10.4
Bromoform				0.50	
Carbon Tetrachloride				0.05	5.97
Chlorodibromomethane	0.17			0.06	0.28
Chloroform		0.45	0.60	3.05	43.7
Cumene	4.00	4.00	3.90		21.5
1,2-Dibromomethane					2.42
Dichlorobromomethane	0.34		0.09	1.75	3.94
1,2-Dichlorobenzene	3.48			18.7	6.12
1,3-Dichlorobenzene					1.09
1,4-Dichlorobenzene				85.1	3.07
1,2-Dichloroethane					
Ethylbenzene				1.85	13.2
1,1,2,2-Tetrachloroethane				0.33	
Tetrachloroethylene	4.50	2.45		19.8	14.3
Toluene		4.75	2.15	11.3	9.95
1,2,4-Trichlorobezene					

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
VOLATILE ORGANICS ug/L					
1,1,1-Trichloroethane				34.9	42.4
1,1,2-Trichloroethane					
Trichloroethylene	0.45	1.76		61.7	9.08
Diiodomethane					
m-Xylene				3.50	10.9
o-Xylene				43.8	19.8
p-Xylene		0.85		5.85	1.50
Dichloromethane					
BASE/NEUTRALS ug/L					
Acenaphthene					
Acenaphthylene					
Anthracene					
Benzidine					
Benzo(a)anthracene					
Benzo(b)fluoranthene					
Benzo(k)fluoranthene					

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
BASE/NEUTRALS ug/L					
Benzo(g,h,i)perylene					
Benzo(a)pyrene					
Bis(2-chloroethoxy)methane					
Bis(2-chloroethyl)ether					
Bis(2-chloroisopropyl)ether					
Bis(2-ethylhexyl)phalate	24.8	20.0	348	2470	77.2
4-Bromophenyl pheyl ether					
Butyl benzyl phalate	23.5			274	
2-Chloronaphthalene					
4-Chlorophenyl phenyl ether					
Chrysene					
Di-n-butyl phthalate				81.3	
Di-n-octyl phthalate					
Dibenzo(a,h)anthracene					
1,2-Dichlorobezene					
1,3-Dichlorobezene					
1,4-Dichlorobezene					

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
BASE/NEUTRALS ug/L					
Nitrobenzene					
Phenanthrene					
Pyrene					
1,2,4-Trichlorobenzene					
PHENOLS ug/L					
2-Chlorophenol					
2,4-Dichlorophenol					
2,4-Dimethylphenol					
4,6-Dinitrol-o-cresol					
2,4-Dinitrphenol					
2-Nitrophenol					
4-Nitrophenol					
p-Chloro-m-cresol					
Pentachlorophenol					
Phenol				395	
2,4,6-Trichlorophenol					

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
PESTICIDES/PCBs ug/L					
Aldrin					
Aroclor 1242					
Aroclor 1016					
Aroclor 1221					
Aroclor 1232					
Aroclor 1248					
Aroclor 1254				0.07	
Aroclor 1260					
a-BHC					
B-BHC					
Y-BHC (lindane)		0.02			0.25
a-Chlordane		0.01	0.10		
g-Chlordane		0.01	0.19		
4,4'-DDD					
4,4'-DDE				0.02	
4,4'-DDT				0.06	
Dieldrin		0.46			

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
PESTICIDES/PCBs ug/L					
a-Endosulfan		0.03			
B-Endosulfan					
Endosulfan sulfate					
Endrin					
Endrin aldhyde					
Heptachlor					
Heptachlor epoxide		0.02			0.291
Methoxychlor					
Mirex					
Toxaphene					
METALS ug/L					
Arsenic	2.2	1		10	13.3
Beryllium					
Cadmium	1.2	1.4		6.5	11
Chromium	5	3	7	37	28
Copper	35	10	42	125	201

EFFLUENTS:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
METALS ug/L					
Lead	5.00	4.60	1.70	4.20	400
Nickel	21.0	19.0	10.0	32.0	44.0
Silver	2.50	0.00	4.40	2.00	4.00
Zinc	125	10.0	22.0	114	2650
TOC (mg/l)	50.0	12.0	33.0	180	92.0

SLUDGE:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
VOLATILE ORGANICS ug/g					
Benzene	1.32	1.26	30.9	2.40	5.80
Cumene		3.29	20.5	10.4	5.80
Ethylbenzene	0.67		2.20	2.20	6.40
Toluene	0.83	1.80	144	5.70	4.30
m-Xylene			3.60	1.20	6.50
o-Xylene	3.28	1.40	15.6	4.00	8.50
p-Xylene	3.01	0.29	4.00	3.70	6.00
BASE/NEUTRALS ug/g					
Acenaphthene					
Acenaphthylene					
Anthracene				32.2	
Benzidine					
Benzo(a)anthracene					
Benzo(b)fluoranthene					
Benzo(k)fluoranthene					
Benzo(g,h,i)perylene					

SLUDGE:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
BASE/NEUTRALS ug/g					
Benzo(a)pyrene					
Bis(2-chloroethoxy)methane					
Bis(2-chloroethyl)ether					
Bis(2-chloroisopropyl)ether					
Bis(2-ethylhexyl)phalate	52.2	100	97.0	1760	1760
4-Bromophenyl pheyl ether					
Butyl benzyl phalate				174	
'2-Chloronaphthalene					
4-Chlorophenyl phenyl ether					
Chrysene					
Di-n-butyl phthalate				266	
Di-n-octyl phthalate					
Dibenzo(a,h)anthracene					
1,2-Dichlorobezene					
1,3-Dichlorobezene					
1,4-Dichlorobezene					
3,3-Dichlorobenzidene					

SLUDGE:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
BASE/NEUTRALS ug/g					
Phenanthrene				32.7	
Pyrene					
1,2,4-Trichlorobenzene					
TOTAL BASE/NEUTRALS	52.2	100	97	2264.9	1760
PHENOLS ug/g					
2-Chlorophenol					
2,4-Dichlorophenol					
2,4-Dimethylphenol					
4,6-Dinitrol-o-cresol					
2,4-Dinitrphenol					
2-Nitrophenol					
4-Nitrophenol					
p-Chloro-m-cresol					
Pentachlorophenol					
Phenol					
2,4,6-Trichlorophenol					

SLUDGE:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
PESTICIDES/PCBs ug/Kg					
a-Endosulfan	104				
B-Endosulfan					
Endosulfan sulfate					
Endrin					
Endrin aldhyde					
Heptachlor		382			
Heptachlor epoxide					
Methoxychlor					
Mirex					
Toxaphene					
METALS ug/g					
Arsenic	7.7	7.5	3.95	25.2	58.8
Beryllium	8.3	2.19	0.1	16.1	
Cadmium	13.4	62.2	12.2	10.7	85.3
Chromium	40.2	146.3	112	7452	229.4
Copper	1259	912.5	287	223	3794

SLUDGE:	Atlantic County	Gloucester County	Hightstown	Kearny	Middlesex County
METALS ug/g					
Lead	287	120.6	2420	970	2606
Nickel	13	98.7	19.2	3132	132.4
Silver	40.4	23.8	107	22.9	60.3
Zinc	1645	1390	477	10903	11559

APPENDIX III

Sludge Study
Key to Plant Abbreviations

ACSA - Atlantic County Sewerage Authority

BCSA - Bergen County Sewerage Authority

BRSA - Bayshore Regional Sewerage Authority

Ess-Un - Essex-Union Joint Meeting

EWWTP - East Windsor Wastewater Treatment Plant

KWTP - Kearny Wastewater Treatment Plant

SRSA - Linden Roselle Sewerage Authority

MCUA - Middlesex County Utilities Authority

PASTP - Perth Amboy Sewage Treatment Plant

PVSC - Passaic Valley Sewerage Commissioners

RVSA - Rahway Valley Sewerage Authority

RSTP - Rutherford/East Rutherford/Carstadt Joint Meeting Sewage Treatment Plant

SLUDGE STUDY RESULTS
FIRST ROUND SAMPLE
CONCENTRATION (mg/kg)

VOLATILE ORGANICS	ACSA	BCSA	BRSA	ESS-UN	EWWTP	KWTP	LRSA	MCUA	PASTP	PVSC	RVSA	RSTP
Benzene	0.3	4.9	1.0	3.8	0.5	4.4	40.4	5.5	1.4	1.5	2.1	13.5
Cumene		7.2	2.2	5.4		38.6	37.5		4.5	5.5	4.8	24.8
Ethlylbenzene		6.2					15.6			7.5	2.1	42.2
Toluene	24.2		9.3		2.4	5.8	958	7.6	0.3	0.9	12.4	60.4
Phenol										150		
BASE/NEUTRALS												
Anthracene												
Bis (2-ethylhexyl) phthalate	88.2	303	89.1	536	114	690	841	605	239	118	2460	525
Butyl benzyl phthalate	10.4					165						185
Di-n-butyl phthalate	4.1					207		0.5	42.7			
1,2-Dichlorobenzene												
Diethyl phthalate		97.4										
Phenanthrene												
1,2,4-Trichlorobenzene												
PESTICIDES/PCBs												
Aldrin	0.1	0.6		0.01								9.3
a - BHC		0.02										
b - BHC	0.3	1.0	0.1	0.5	0.2		13.4		0.4		0.4	6.6
y - BHC (Lindane)	0.3		0.2	1.0	0.6				0.1			

SLUDGE STUDY RESULTS (Continued)
FIRST ROUND SAMPLE
CONCENTRATION (mg/kg)

	ACSA	BCSA	BRSA	ESS-UN	EWWTP	KWTP	LRSA	MCUA	PASTP	PVSC	RVSA	RSTP
Chlordane	0.8			0.4	8.9						1.5	
4,4'-DDD						212						
4,4'-DDE	0.01			0.03	0.06	0.1	0.9	0.4				
4,4'DDT						0.1						
Dieldrin			0.4	0.05								
a - Endosulfan												
Heptachlor									0.2	2.3	0.001	
Heptachlor epoxide		0.04					1.5					9.8
METALS												
Arsenic	1.3	0.6	3.6	0.7	3.6	20.2	1.8	4.6	2.6	6.51	0.5	3.7
Beryllium	0.3	0.2	0.4	0.1	0.4	1.6	0.3	2.2	0.3	<0.2	0.1	<0.1
Cadmium	2.9	243	1.7	165	5.1	6.3	676	49.2	17.2	19.4	6.5	79.4
Chromium	26.3	230	60.7	74.4	66.8	10,142	244	9.1	205	798	104	254
Copper	500	4730	224	2083	825	663	2900	1967	672	873	2313	627
Lead	139	930	41.7	875	167	372	1864	1298	356	1434	264	314
Mercury	3.8	40.8	2.9	21.4	16.9	2.3	10.8	4.1	3.8	8.2	5.0	112
Nickel	8.7	1500	61.6	324	46	113	889	42.6	16	535	226	143
Silver	10.3	164	2.5	44.6	83.1	233	49.5	91.8	4.8	8.8	96.5	40.5
Zinc	335	3420	317	2643	1706	661	2770	3305	3908	770	2778	692

SLUDGE STUDY RESULTS
SECOND ROUND SAMPLE
CONCENTRATION (mg/kg)

VOLATILE ORGANICS	ACSA	BCSA	BRSA	ESS-UN	EWWTP	KWTP	LRSA	MCUA	PASTP	PVSC	RVSA	RSTP
Benzene	11.4	9.7	6.5	23.0		5.6	40.5		4.1	8.9	13.2	154
Cumene	5.0						19.1	7.6	6.5	4.7		164
Ethylbenzene	1.4	11.7		5.4		1.1	26.9		7.2	5.5	15.6	378
Toluene	10.1	12.2	10.1	11.4		65.1	6610		5.2	5.8	22.2	93.3
Phenol										23.3		
BASE/NEUTRALS												
Anthracene						34.4			80.1			
Bis(2-ethylhexyl) Phthalate	104	120		149	76.9	1050	244	151	87.0	83.1	904	365
Butyl benzyl phthalage	1.2					94.9			16.2			328
Di-n-butyl phthalate						270						
1,2-Dichlorobenzene												
Diethyl phthalate								10.4		56.4		
Phenanthrene						32.0			74.4			
1,2,4-Trichlorobenzene										5.5		
PESTICIDES/PCBs												
Aldrin	0.03									1.0		
a - BHC		0.0005										
b - BHC	1.0	0.8	0.3		0.4		3.6		0.2		0.1	
v - BHC (Lindane)			0.1		2.4			19.3	0.04			

SLUDGE STUDY RESULTS (Continued)
SECOND ROUND SAMPLE
CONCENTRATION (mg/kg)

	ACSA	BCSA	BRSA	ESS-UN	EWWTP	KWTP	LRSA	MCUA	PASTP	PVSC	RVSA	RSTP
Chlordane	1291			2155			7880				195	
4,4'DDD												
4,4'DDE				0.6				0.5				
4,4'DDT		0.6					0.02					
Dieldrin					0.2							
a - Endosulfan												
Heptachlor									0.05			
Heptachlor epoxide			0.07				0.5				0.06	0.6
METALS												
Arsenic	20.0	6.3	87.5	7.4	3.1	11.6	32.4	7.9	1.1	8.23	4.9	30.5
Beryllium	0.3	0.1	0.1	0.5	3.5	0.8	2.5	3.0	0.3	0.37	0.3	0.3
Cadmium	6.8	46.9	2.5	52.9	7.1	7.9	58.2	35.6	3.1	29.8	9.1	563
Chromium	25.1	27.8	92.1	57.7	41.1	667	193	238	6.5	255	30.6	1721
Copper	448	1778	292	2144	671	1303	3782	2026	582	1305	1807	4675
Lead	121	383	49.2	913	80.8	452	1964	503	212	1615	4518	3636
Mercury	1.2	9.0	2.6	20.9	11.6	6.1	9.8	0.9	1.6	7.36	4.4	221
Nickel	22.9	220	218	370	158	1277	2047	45	18.1	141	249	1367
Silver	24.6	43.6	18.8	43.7	137	2.9	82.2	54.0	4.5	4.1	41.2	240.3
Zinc	663	2278	544	4726	959	2784	8669	12169	2052	1890	5621	13377

SLUDGE STUDY RESULTS
THIRD ROUND SAMPLE
CONCENTRATION (mg/kg)

VOLATILE ORGANICS	ACSA	BCSA	BRSA	ESS-UN	EWWTP	KWTP	LRSA	MCUA	PASTP	PVSC	RVSA	RSTP
Benzene	0.5	5.2	10.8	25.4		10.4	34.1	6.5	1.6	14.1	11.4	281
Cumene						8.7	20.4	12.0	0.6	13.6		281
Ethlylbenzene		1.8		4.4		0.8	23.9	6.7	0.2	5.3	4.1	535
Toluene		0.9	10.9	6.7		2.8	555	199	0.3	4.7	1.0	333
Phenol										53.9		
BASE/NEUTRALS												
Anthracene												
Bis(2-ethylhexyl)	190	242	151	226	102	5720	552	1990	21.2	101	3080	48.1
Butylbenzyl phthalate						658						
Di-n-butyl						529			7.6			
1,2-Dichlorobenze							157					
Diethyl phthalate												
Phenanthrene												
1,2,4-Trichlorobenzene												
PESTICIDES/PCBs												
Aldrin	0.001	0.04								11.9		
a - BHC											0.03	
b - BHC	0.4	0.6	0.3		0.1	274	4.0				0.08	
v - BHC (lindane)					0.09			0.9		0.01		

SLUDGE STUDY RESULTS (Continued)
THIRD ROUND SAMPLE
CONCENTRATION (mg/kg)

	ACSA	BCSA	BRSA	ESS-UN	EWWTP	KWTP	LRSA	MCUA	PASTP	PVSC	RVSA	RSTP
Chlordane	0.19	0.6	3.3						1.1		0.4	
4,4'DDD	0.06		0.05		0.1							
4,4'DDE				1.4								
4,4'DDT												
Dieldrin												
a - Endosulfan				0.3								
Heptachlor												
Heptachlor epoxide			0.4		0.09		1.5			0.008		
Mirex				1.0								
METALS												
Arsenic	60	28	18	23	11.0	125	98	25	40	153	23	56
Beryllium	0.2	0.2	0.3	0.1	4.1	0.3	0.7	0.9	0.2	0.1	0.2	0.1
Cadmium	8.8	127	2.3	64.8	7.1	6.4	68.7	37.7	165	35.8	126	161
Chromium	27.9	1273	785	931	54.7	2245	3791	285	132	1094	95.8	415
Copper	632	3715	368	2778	973	4908	5385	2575	645	779	2204	1140
Lead	172	427	81.5	668	80.8	300	336	747	232	849	140	625
Mercury	1.5	10.8	3.3	19.9	13.7	2.6	4.4	4.7	0.9	4.8	5.5	282
Nickel	562	861	283	291	280	251	1978	249	52.7	110	635	408
Silver	25.4	130	11.5	117	106	198	154	163	13.6	10.3	108	3.3
Zinc	954	3030	6005	4130	1507	1020	7697	5967	7620	4530	5030	2624

APPENDIX IV