Trackdown of Polychlorinated Biphenyls (PCBs) In a Municipal Sewer System: Pilot Study at the Camden County Municipal Utility Authority (CCMUA)

Thomas Belton[a1], Edward Stevenson[a], Lee Lippincott[a], Randy England[a,] Bruce Ruppel[a], John Botts[b] and Gregory Cavallo[c]

[a]New Jersey Department of Environmental Protection, Division of Science Research and Technology, 401 East State Street, PO Box 409, Trenton NJ 08625
[b]Aquatic Sciences Consulting, 15751 Bushy Park Rd., Woodbine MD 21797
[c]Delaware River Basin Commission, Toxics Evaluation & Management Section, 25 State Police Drive, PO Box 7360, West Trenton NJ 08628

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ABSTRACT

A field investigation or Pilot PCB source trackdown study was performed in the sewer collection system of the Camden County Municipal Utility Authority (CCMUA) to evaluate the most appropriate sampling and analytical techniques for tracking down PCB contamination to the MUA collection system and to identify potential upland sources. Innovative field and analytical methods were evaluated including the use of PCB analytical Method 1668a to attain high sensitivity and low detection limits; the quantitation of over 124 separate PCB congeners as a mean to identify unique source signatures through pattern recognition; the use of passive in-situ continuous extraction sampler (PISCES) for sample integration over protracted time periods (14 days); and the use of and electronic data collection system for hazardous waste sites interfaced with a geographic information system (GIS) to facilitate the identification of potential upland contaminant sites as PCB sources. Analytical results from the Pilot Study showed quantifiable levels of PCBs in the CCMUA wastewater at all sampling locations (i.e., both urban and suburban) and in all sampling media (i.e., wastewater and PISCES hexane) potentially from varied sources (i.e., as indicated by differences in PCB congener profiles between waste streams). High concentrations of total PCBs were found in both whole water 24 hr. composites (Mean: 189 ng/l; Range: 33 ng/l to 784 ng/l) and grab samples (Mean: 41 ng/l; Range: 20 ng/l to 82 ng/l). Fourteen day PISCES hexane samples also showed consistent high levels of PCBs in the waste stream, although the results were skewed to the lower chlorinated congeners ostensibly because the more highly chlorinated PCBs tend to adhere to particulates, which do not efficiently cross the PISCES semi-permeable membrane. Potential upland sources of PCBs to the CCMUA collection system, as screened by the DEP HazSite and GIS databases, were tentatively identified as contaminated sites, metal shredders, aluminum smelters, electrical substations, landfills, and area-wide atmospheric deposition.

KEYWORDS: polychlorinated biphenyls, PCBs, Aroclor, PISCES, trackdown, MUA, TMDL,

1.0 INTRODUCTION

In 1998, using a new analytical methodology of high resolution gas chromatography/high resolution mass spectrometry or HRGC/HRMS (EPA Method 1668A), the Delaware River Basin Commission (DRBC) performed a PCB loadings study on the Delaware Estuary and found PCBs in effluents from five large sewage treatment plants and one industrial facility. Total PCB results ranged from 1,430 to 45,140 picograms/L during dry weather, and 2,020 to 20,240 pg/L during

[1] Corresponding Author. *E-mail address*: Thomas.Belton@dep.state.nj.us

wet weather. Subsequently, in the spring of 2000, ninety-four dischargers (NPDES permittees) to the Delaware Estuary from three different states were asked to conduct both continuous and stormwater discharge monitoring for eighty-one (81) PCB congeners utilizing Method 1668A. Results indicated that loadings of PCBs to the Delaware Estuary management zones (Figure 1) from point sources were significant and of such magnitude as to cause the water quality standards to be exceeded. The water quality PCB criteria for Zone 3 of the Delaware Estuary (near Camden, New Jersey) is 44.4 picograms per liter. During this year 2000 sampling period the Camden County Municipal Utility Authority (CCMUA) collected three wet weather and three dry weather samples and consistently found all ten homologs of PCBs to be present in their effluent, and with loadings of 819 mg/day, or at levels that exceed ambient water concentrations of PCBs in river by three orders of magnitude (USEPA 2003).

Because of the high background levels and ubiquity of PCBs in the environment due to both historical discharges and ongoing approved uses, the Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) for Zones 2-5 of the Tidal Delaware River estuary (USEPA 2003) stipulates that facilities that discharge to the River, including its tributary streams, must develop and implement a waste minimization and reduction plan (WMRP) which shall include:

- A list of all known and suspected point and non-point sources of PCBs;
- ***A description of studies used to trackdown PCBs;***
- A description of actions to minimize the discharge of PCBs;
- A proposed time frame for PCB load reductions; and
- A method to demonstrate progress, and required PCB monitoring.

However, due to the lack of a standardized approach in tracking down PCB sources released to MUAs (i.e., hundreds of miles of piping in their collection system, numerous industrial significant users, and undefined non-point loads from stormwater runoff), a method was needed to investigate where PCBs might be coming into the collection system so as to initiate waste minimization and load reduction strategies as required by the WMRP. Therefore, under a cooperative agreement with DRBC, a Pilot Study to monitor MUAs in Camden, New Jersey; Wilmington, Delaware; and Philadelphia, Pennsylvania (Figure 1) was undertaken. This report includes the results of the Camden, New Jersey Pilot Study.

The primary goals of the Pilot Study are: 1.) To evaluate the most appropriate sampling and analytical techniques for tracking down PCB contamination in the CCMUA sewer collection system, and 2.) To identify potential upland sources for follow up assessment. Innovative methods evaluated included the use of PCB analytical Method 1668a to attain high sensitivity in sampling; quantification of 124 separate PCB congeners as a mean to identify unique source signatures; the use of passive in-situ continuous extraction samplers (PISCES) for sample integration over long time periods (14 days); and the use of NJDEP's Site Remediation Program's HazSite electronic data collection system in conjunction with a geographic information system (GIS) to screen and isolate potential upland sources for further investigatory actions.

Figure 1. Management Zones Delaware River Estuary

2.0 METHODS

2.1 Sewer Sheds and Site Sampling Selection

The piping and infrastructure of the CCMUA collection system had been surveyed and mapped previously delineating five major and separately drained county-wide sub-basins (Figure 2). In addition, CCMUA and the City of Camden have further delineated into sub-basins as part of a Combined Sewer Outfall (CSO) Modeling Study (CH2M Hill 1999a) performed in conformance with NJ Sewage Infrastructure Improvement Act (SIIA) planning requirements.

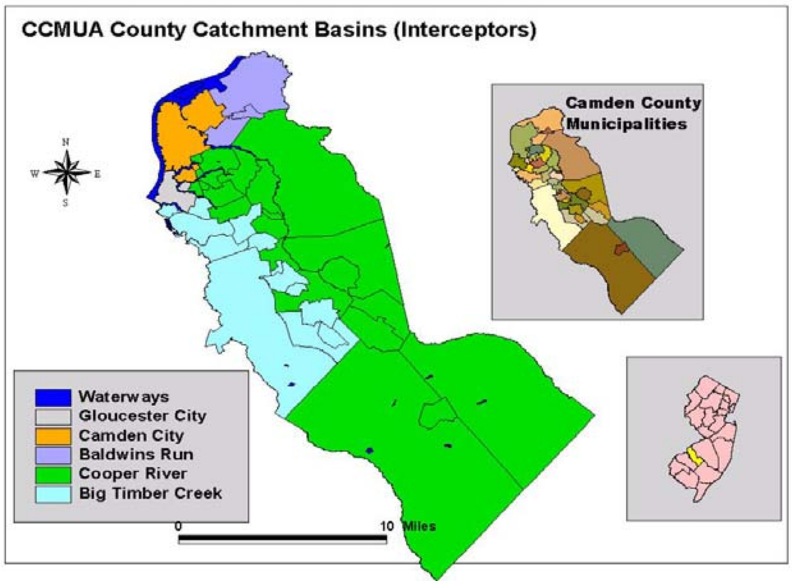

Figure 2.

In 1997 NJDEP adopted technical rules for site remediation (NJAC 7:26E) with requirements that all hazardous site investigations in the State of New Jersey (i.e., public and private) must deliver investigative data in a digital format with information that contains the spatial distribution and concentration of different contaminants (e.g., PCBs) in the environment (i.e., called the HazSite Database). HazSite is designed to enable the importation of site data to GIS for visualization, distribution and further analysis. The Pilot Study used the data set in a unique fashion as a screening methodology for estimating sources possibly associated with non-point runoff to sewer and storm collection systems (Figure 3).

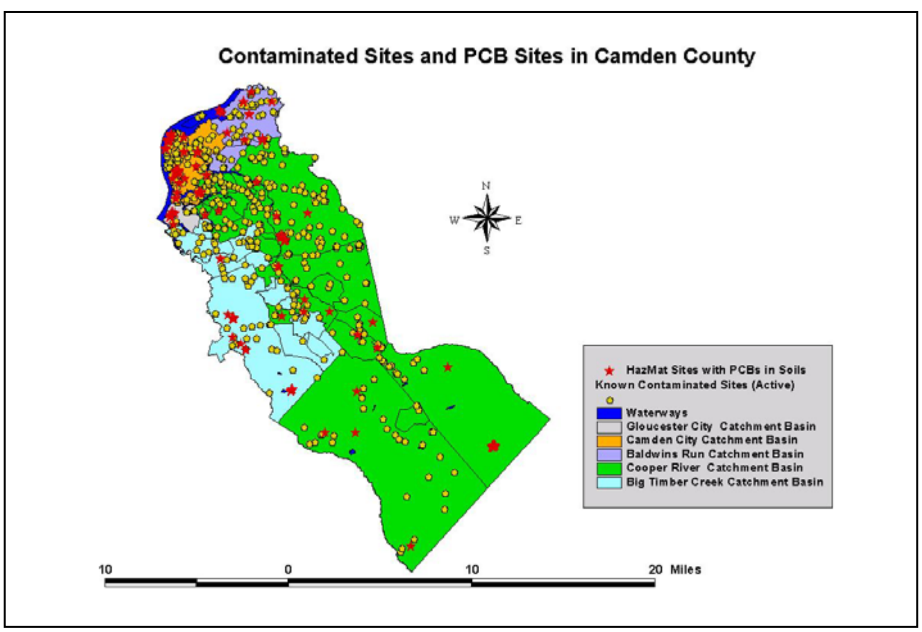

Figure 3.

Based on the HazSite database and the CSO sewer-shed delineations, and in coordination with CCMUA and City of Camden Engineers, we chose seven monitoring locations for the pilot study within the municipal boundaries of Camden City (Figure 4), each station draining and representing a separate sub-basin of interest as a potential source of PCBs.

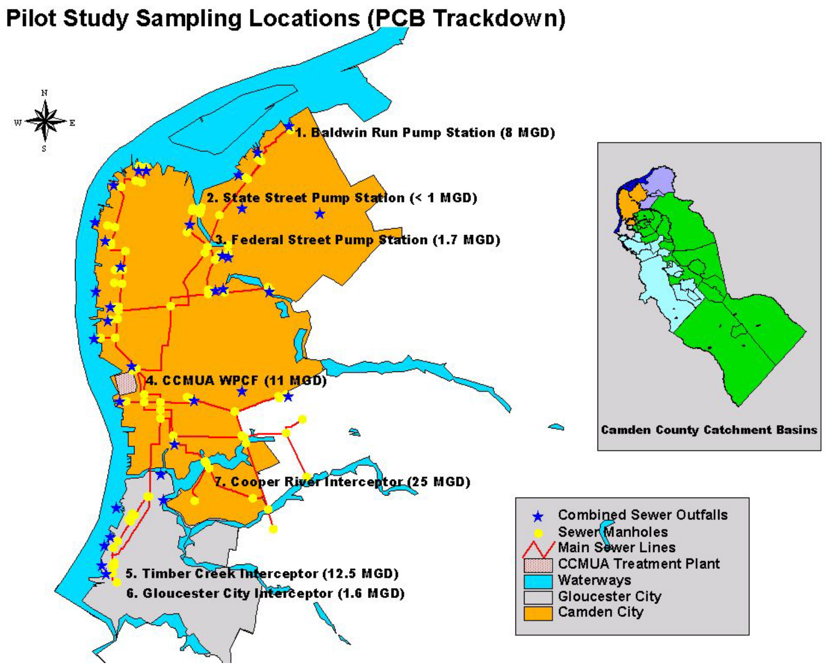

Figure 4. Sewer Sampling Locations

The rationale for these sampling locations follow:

1. Baldwin St Pump Station	Drains North Camden and all Pennsauken (Industrial Park and CSOs) Delaware River (CSO Nearby) **Flow: 8.0 MGD**[2]
2. State Street Pump Station	North Camden Industrial Area Cooper River (CSO Nearby) **Flow: < 1.0 MGD**
3. Federal St Pump Station	Pavonia Yards (Conrail) Scrap Yards and Metal Reclamation Shops Cooper River (CSO Nearby) **Flow: 1.7 MGD**
4. CCMUA WPCF#1	All Camden City and Waterfront (excluding Baldwin Run) **Flow: 11.0 MGD**
5. Timber Creek Interceptor	Camden County (suburban): Big Timber Creek Municipalities (No storm flows and no city flows) **Flow: 12.5 MGD**
6. Gloucester City Interceptor	Drains All Gloucester City Industrial and CSOs **Flow: 1.6 MGD**
7. Cooper River Interceptor	Camden County (suburban): Cooper River Municipalities and some Atlantic County (No storm flows and no city flows) **Flow: 25.0 MGD**

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[2] (MGD) Millions of gallons per day. Flows are modeled estimates from CH2M Hill, 1999a (Table 2-1) and CCMUA 1997.

2.2. Field Procedures

2.2.1 Whole Water Sampling

Whole water samples were collected using ISCO pump samplers. Whole water samples were collected as twenty-four composite on July 7-8, 2003 and grab samples on July 9 and 10, 2003. Sampling was implemented during dry weather in July with no preceding rainfall (i.e., > 0.1 inch of rain with duration of at least an hour within 72 hours of initial deployment. Twenty-four hour whole water composite samplers (ISCO) were deployed at each sampling location, usually suspended by harnesses to the sewer ladders and the manhole covers replaced, or free standing in locked Pump Stations. After 24-hours, the composite samples (8 Liters) were retrieved and placed into coolers, a field report and Chain of Custody form completed, then samples were shipped to AXYS Labs. Immediately after the 24-hours composite sample was collected the ISCO pumps were used to pull an additional grab sample (2.5 liter) from each manhole. A field and trip blank were included with each sampling round using nanopure water provided by lab.

2.2.2. PISCES Sampling

PISCES samplers consist of brass pipes, fittings and a semi-permeable membrane filter with hexane as the sampling medium. When submerged in water, dissolved hydrophobic molecules like PCBs pass through the membrane and accumulate in the nonpolar hexane. Two PISCES samplers per station were deployed in parallel (Figure 5) as per Litton et al. (1993) with a protective shield placed around them to minimize potential damage to the membrane from debris and turbulent flows in the sewers (Figure 5).

Figure 5.

Temperature was monitored continuously during PISCES sample collection using Hobo XT temperature sensors and data loggers (every 12–16 min) since the sampling rate of PISCES is strongly influenced by temperature. Temperature data was used to estimate the PISCES sampling rates since PCB uptake is a function of the membrane area and the temperature of the water being sampled (NYDEC 1997a). Average temperature values and the membrane area were entered into an equation to estimate the sampling rate. The sampling rate was used to define the equivalent volume of water sampled during deployment, which is then used to calculate the average PCB concentrations in the water during the sampling period.

PISCES samples were collected over a 13 to 14 day deployment (July 9-23, 2003) during dry weather and with no preceding rainfall (i.e., > 0.1 inch of rain with duration of at least an hour within 72 hours of initial deployment), however we did capture a significant rain event during its fourteen day deployment. The two PISCES units per site were then retrieved and decanted into pre-cleaned lab jars onsite. The PISCES units and blanks were filled with the same grade of hexane used by laboratory for sample extractions. Only one of the two PISCES samples was chosen for shipment and PCB analysis by Lab, the other being archived by NJDEP.

2.3 Analytical Procedures

All samples were collected, documented with chain of custody provisions, and shipped cold to AXYS analytical laboratories for PCB congener analysis. There they were analyzed for 124 PCB congeners (Table 1) by USEPA method 1668A (USEPA 1999) with slight modifications as performed by an analytical contract lab (AXYS Labs) using HRGC/HRMS. The 124 PCB congeners were selected in consultation with DRBC after a literature review of other PCB congener studies performed in the Delaware River Basin, and comparisons with data sets from DNREC, DRBC, Rutgers and University of Maryland studies.

Table 1. Target Analytes for PCB Congeners

PCB IUPAC Congener Numbers for Analysis				
1	32	82	135	181
3	33	83	136	183
4	37	84	137	185
5	40	85	138	187
6	41	87	141	189
7	44	89	146	190
8	45	90	149	191
10	46	91	151	193
11	47	92	153	194
12	48	95	156	195
13	49	97	157	196
14	51	99	158	197
16	52	101	163	198
17	53	105	166	199
18	56	107	167	200
19	60	110	168	201
21	63	114	170	202
22	64	118	171	203
24	65	119	172	204
25	66	123	174	205
26	70	128	176	206
28	74	129	177	207
29	77	130	178	208
30	80	132	179	209
31	81	134	180	

For the PISCES sample analyses (lab grade hexane) the extraction step in Method 1669a proved unnecessary (i.e., PISCES hexane-water exposure essentially mimics lab extraction) and omitted. The sample was spiked with surrogate standard solution and then dried over sodium sulphate before proceeding with the column chromatography cleanup. All detectable congeners are reported and half the detection limit for non-detected values. The assumption of using ½ DL is justified since most samples exhibited detectable concentrations of PCBs. Sample analysis by AXYS Labs was performed in two batch loads. Batch 1 showed acceptable QA recoveries and the absence of any quantifiable contamination in field, trip, or lab blanks. Batch 2 however, showed PCB 209 in the procedural blank, therefore this analyte was flagged not quantifiable for all samples in that batch.

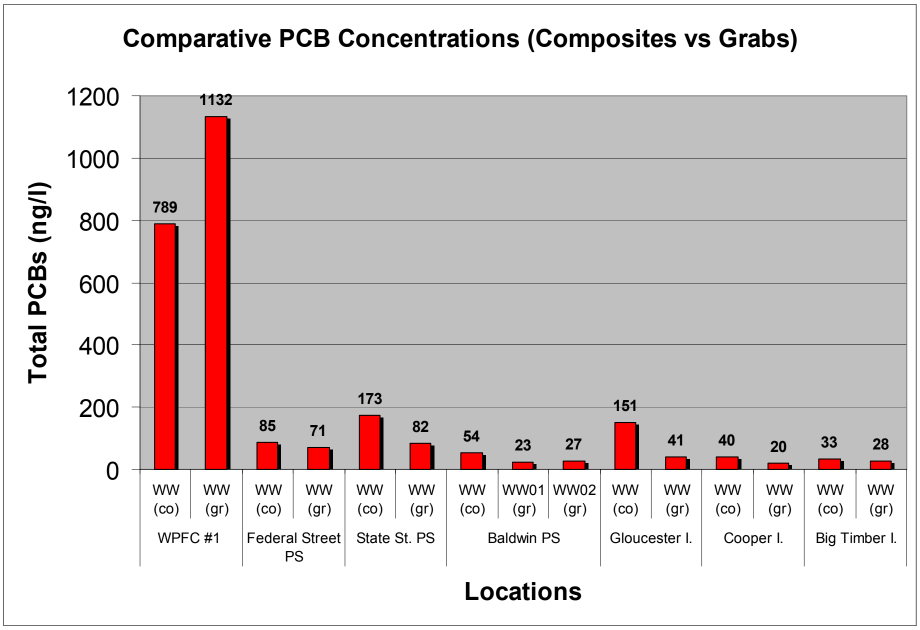
3.0 RESULTS

3.1 Whole Water Samples

Detectable levels of PCBs were found in all whole water-wastewater samples and at all sampling locations (i.e., both urban and suburban), and in all sampling types and media (i.e., wastewater composites and grabs, PISCES hexane). Sampling results are presented as PCB congeners, PCB homolog groups, and total PCBs in Appendix 1 (Table 2).

Higher concentrations of PCBs were found in whole water composites (See Figure 6) with a Mean of 189 ng/l PCBs and a Range of 33 ng/l to 784 ng/l versus grab samples with a Mean of 41 ng/l PCBs and a Range of 20 ng/l to 82 ng/l. However, quantifiable levels in the grab samples (at an order of magnitude above the analytical detection limits of EPA Method 1668a) indicates that the more expensive and time consuming 24-hour composite may not be necessary, at least for a quick source trackdown result when a yes-or-no answer (as to the presence of PCBs in the sample) is more indicative of nearby sources than actual quantitation.

Figure 6.



However, for the purposes of upland source identification we used the 24-hr composite result for congener fingerprinting due to the longer exposure times. In Figure 7 we overlay the 124 PCB congeners for each station, log-normalized to allow between-station comparisons, and to see suspect divergent distributions (possibly indicating descriminant source signatures).

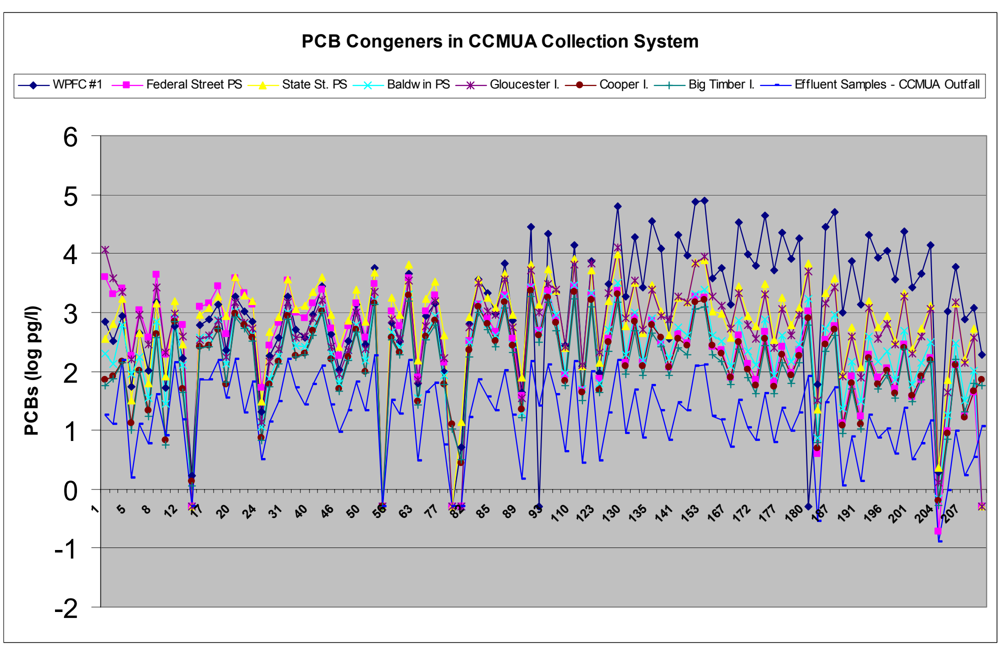


Figure 7. PCB Congeners in 24-hr wastewater Composite Samples (log-normalized)

We might also see differences between site PCB signatures by presenting the results in homolog distributions (i.e., grouping PCB congeners by degree of biphenyl chlorination), which can reveal subtleties about source stream differences and perhaps about types of sources (Figure 8).

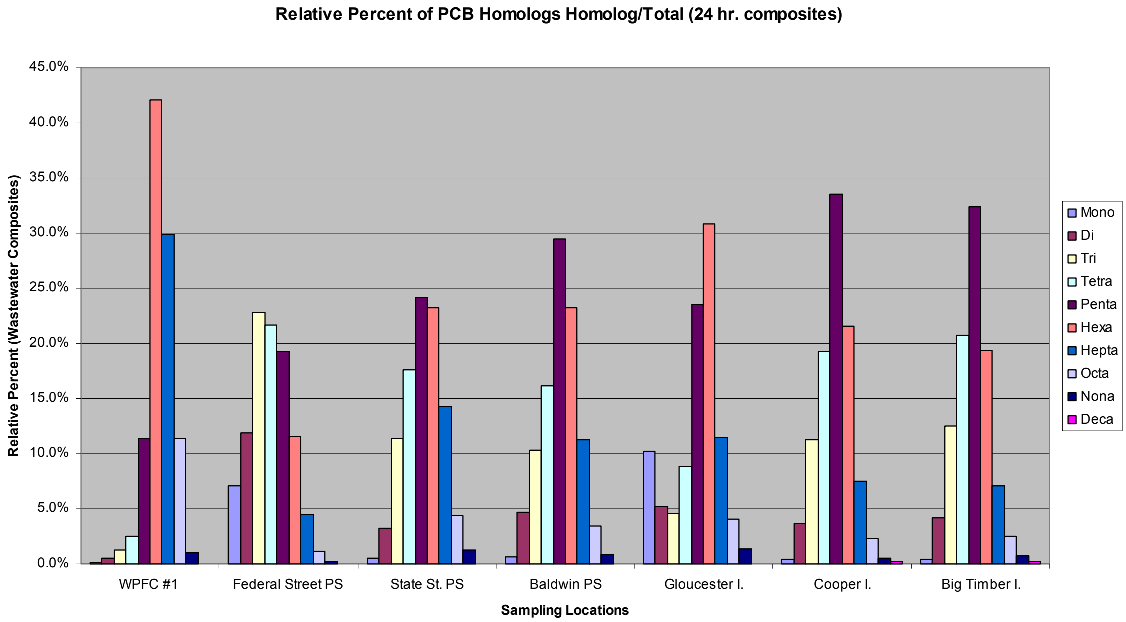


Figure 8.

For example, the Federal Street and State Street Pump stations have an overwhelming makeup of lower chlorinated PCB homologs (i.e., mono, di and tri), which may be indicative of recent discharges where these more volatile low chlorinated PCBS have not yet had a change to evaporate. They may also be a by-product of the pumping process itself but interestingly the homolog distribution at WPCF#1 is depauperate in these same highly volatile homologs perhaps indicating that the PCBs have been dissipated through volatilization and released to the atmosphere along the numerous pipe and vet routes through central Camden on their way to the treatment plant

Historically, attempts at isolating PCB source signatures have looked at Aroclor distributions of homologs (Frame et al. 1996 and Figure 9). Aroclor is the trade name under which PCBs were manufactures by General Electric and sold for various end uses until they were banned for production and their uses curtailed under the Toxic Substances Control Act. For example, if look at the apparent Aroclor distribution of PCB homologs at the Federal Street Pump Station with its collection of lower chlorinated congeners (Figure 10) the sample looks like a mix of Aroclors A1242 and A1248. Water from WPCF#1 (Figure 11) on the other hand, which integrates Federal Street flows with other industrial flows by the waterfront appears looks more like A1260.

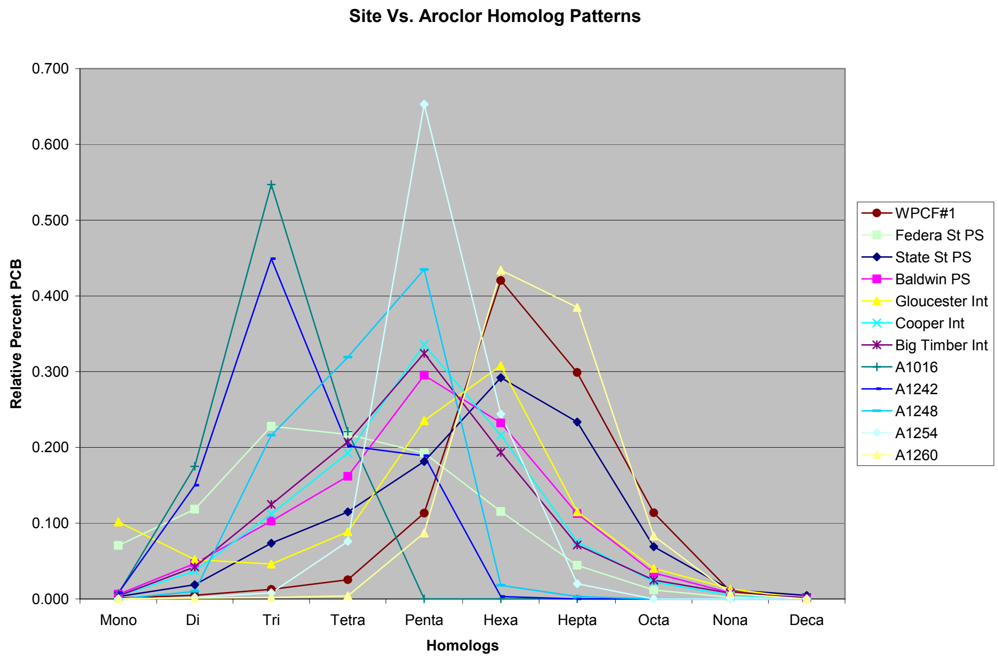


Figure 9. PCB Homologs as Aroclors

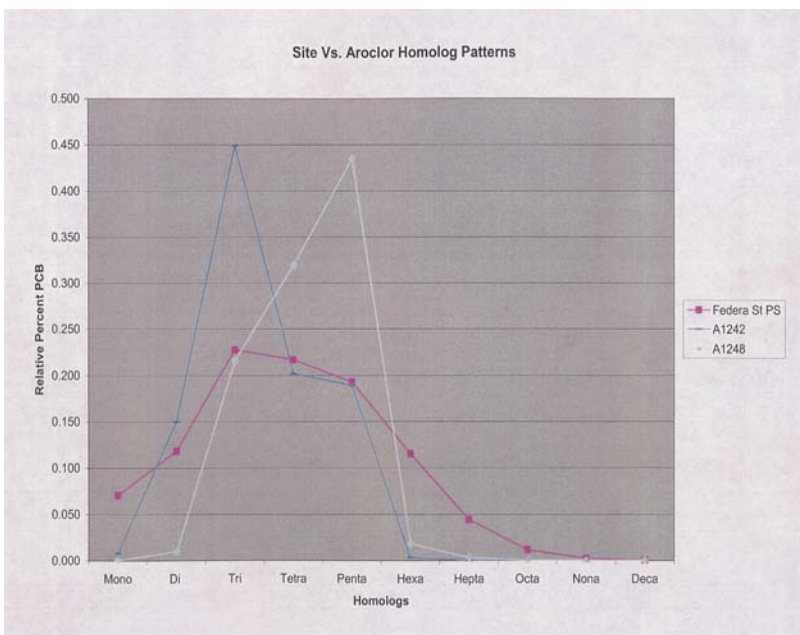


Figure 10. PCB Homologs as Aroclors at the Federal Street Pump Station

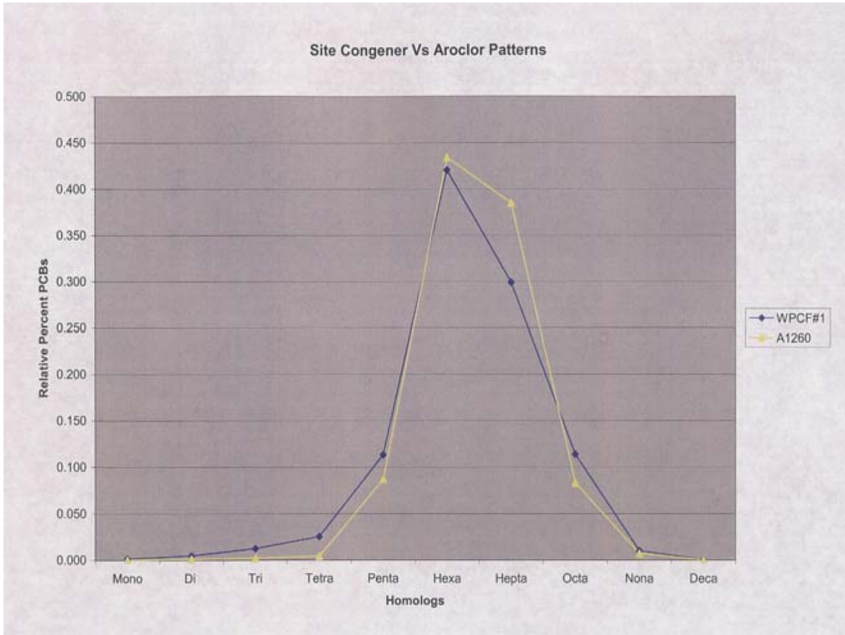
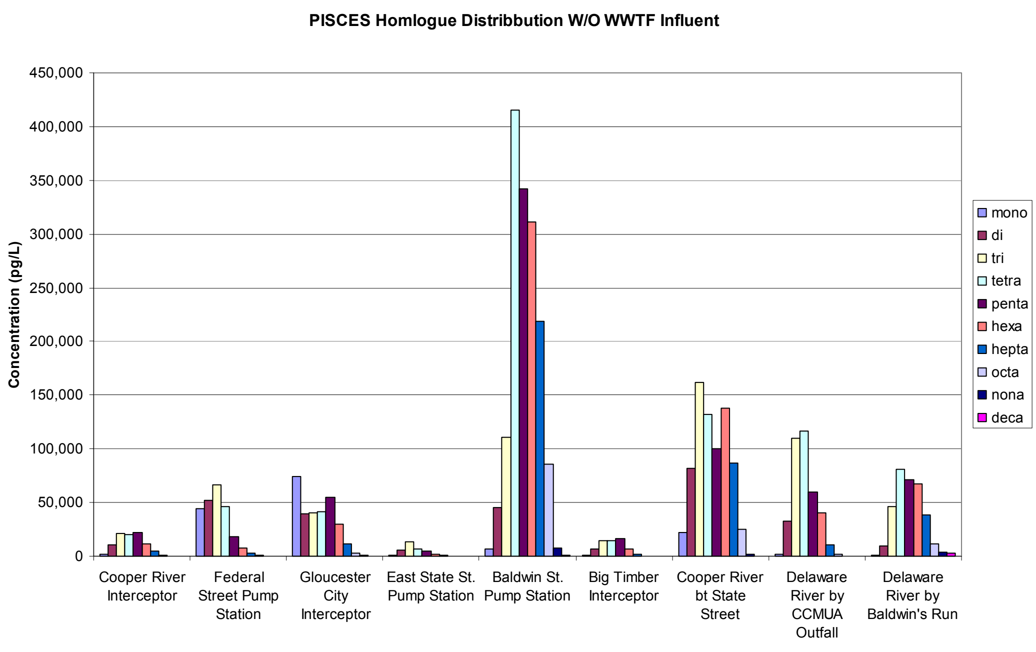


Figure 11. PCB Homologs as Aroclor at WPCF#1

3.2 PISCES

PISCES results are reported in ng/sample (since they integrate over a period of 14 days) but were converted to ng/l by a procedure developed by (Litten et al, 1993) which allows one to estimate the amount of PCBS in the surrounding water if certain physical features are known (i.e., temperature). PISCES PCB results in both the hexane fraction and the estimated water quantities also show consistent levels of PCBs in the waste stream (Appendix 1), although the congener results for PISCES were skewed more to the lower chlorinated PCBs, since the higher chlorinated PCBs tend to adhere to particulates which do not cross the PISCES sampling membrane efficiently. PISCES results confirm significant yet differential amounts of PCBs coming from various sewer-sheds (from as yet unknown sources) including both suburban and city interceptors (Figure 12).



The WPCF #1 Interceptor at CCMUA which integrates almost all of Camden City's wastewater had the highest concentration of PCBs in PISCES. Timber Creek and Baldwin samples were also high whereas the East State Street and Federal Street samples were among those with the lowest PCB levels. Since both State Street and Federal Street flows eventually merge at WPCF#1 it may be that some significant sources of PCBs occur along the collection system between these sampling sites allow us to narrow any future PCB source searches to facilities or sites in between.

4.0 DISCUSSION

4.1 Field Methods Evaluation

Concentration of PCBs were found and quantified in CCMUA wastewater at all sampling locations (i.e., both urban and suburban) and in all sampling media (i.e., wastewater composites, grabs samples, and PISCES hexane) potentially from varied sources (i.e., as indicated by differences in PCB congener profiles and homolog distributions between sampling sites and associated waste streams). The whole water sampler has the advantage of collecting total PCBs (i.e., PCBs both soluble and attached to suspended solids) whereas PISCES only collects PCBs that diffuse through its semi-permeable membrane (i.e., dissolved/soluble). This limits somewhat PISCES application as a tool for source identification through pattern recognition. This is somewhat offset by the advantage of PISCES in its ability to integrate PCB concentrations over an extended sampling period (e.g., 7 to 10 days).

Comparing the results of the three methods ; 24-hr composites, grab samples and PISCES we can see that they all can be used to identify PCBs in a MUA waste stream. The benefits of each approach however must be weighed against the logistical aspects and the disadvantages for the second and possibly more critical goal of source identification. PISCES advantages of long-term deployment is offset by the difficulty of deployment (i.e., keeping a bulk sampler in place within a confined turbulent pipe) and its limited ability to identify the more highly chlorinated PCB congeners (i.e., usually transported on suspended solids) and which may be a significant component in most commercial PCBS historically discharged to the environment.

Grab samples allow a quick ad less expensive mode of sampling, and in conjunction with the low detection sensitivity associated with Method 1668a allows a practical means to get a more complete answer as to PCB presences in wastewater and the relative patterns of PCB congeners. 24-hr composite samples in conjunction with Method 1668a allow the most confidence in sampling results since the PCB concentration are higher, the patterns of PCBS probably more complete since integrated over a longer period of time and is the best means to match with upland soil, sediment or aqueous samples once a candidate site has been identified through HazSite/GIS screening.

4.2 Upland Source Identification

The Pilot Study area was evaluated using a series of detailed maps (Figures 3 and 4), and aerial photography (Figure 5) using SRP's GIS coverage and EQuIS data sources from active site investigations to populate a series of analysis templates for showing sites with known PCB contamination (or in adjacent sediments).

Figure 5.

However, besides hazardous waste sites, a universe of other potential PCB sources may be targeted for follow-up investigations. These potential non-point sources of PCBs include: closed sanitary landfills, remediated and un-remediated contaminated sites, metal reclamation facilities, aluminum smelters, and electrical substations.

In addition to these non-point sources, ongoing industrial or commercial operations that currently discharge to the CCMUA collection system may be sources of PCBs, either through inadvertent by-products generation, or else from aging infrastructure within the facility (e.g., leaking PCB electrical equipment, paints, sealants, etc.). A number of these PCB associated industry types are known from their industrial SIC Codes (Table 3).

Table 3. Potential PCB Point Sources by SIC Code*

SICode	Code Name Facilities
26	Paper and Allied Products
30	Rubber and Misc. Plastics
33	Primary Metal Industries
34	Fabricated Metal Products
37	Transportation Equipment
49	Electric, Gas, and Sanitary Services

* Industries with Known Capacity to Use or Generate PCBs

An aggressive means to narrow down which ones might be current sources to an MUA could include a one-time permit provision for PCB sampling at point they enter the CCMUA collection system (allowed under the NPDES Pretreatment Rules) using a high resolution GC/MS method (e.g., Method 1668a). Each and any of the above trackdown activities could then be utilized as part of the waste minimization and reduction plan (WMRP) required under the TMDL.

It should be noted that a potential confounding factor affecting our sewer-based ability to localize land-based sources of PCBs to the CCMUA collection system may be air pollution over the industrialized Philadelphia-Camden airshed (Eisenreich and Reinfelder, 2002; VanRy, et al. 2002). The New Jersey Atmospheric Deposition Network study has found that:

- The urban/industrial area of Camden New Jersey emits PCBs in gas-phase, particulate and wet deposition, resulting in PCB concentrations which are among the highest ever recorded. This local signal is, however, diluted to continental background within tens of kilometers of Camden.
- There is a strong correlation between urbanization and PCB concentrations suggesting that atmospheric PCBs may arise from highly localized, urban sources.

- A comparison of individual PCB congener profile concentrations (in gas phase) between sites indicates that Camden is the second most dissimilar (among network), which may reflect a strong source located near the Camden sampling site that generates extremely high gas-phase PCB concentrations.

4.3 Loadings

Although the mass-balance, or loadings, of PCBs to CCMUA were not a primary goal in the PCB source trackdown study, we felt it worthwhile to compute the loadings from these different sewer-sheds as a means to prioritize future trackdown investigations since small, cumulative source concentrations in a larger flow, may far outweigh in significance a higher concentration in a more decreased flow.

Table 4. Estimated PCB Loadings by Sewer Shed (pg/l)

Location	Concentration (pg/l)*	Flow (MGD)**	Load (gm/day)	Land Use
Baldwin Run	53,839	8.0	1.63	Urban
State St.	173,466	1.0	0.66	Urban
Federal St.	85,373	1.7	0.55	Urban
WPCF	798,081	11.0	33.23	Urban
Cooper R.	40,107	25.0	3.80	Suburban
Big Timber	32,763	12.5	1.60	Suburban
Gloucester	151,088	1.6	0.92	Urban

* 24 hr composite results
*Estimated Flows from CH2M Hill CSO Modeling Report for CCMUA (CH2M Hill 1999a).

The largest PCB load is from WPCF#1 which integrates all of Camden City's urban industrial flows. The next largest load is surprisingly the Cooper River Interceptor, primarily a suburban flow, which has about the same PCB load as the urban Baldwins Run site, which integrates flows from all industrial Pennsauken and North Camden. In addition, Big Timber Creek, our other suburban flow, has approximately twice the PCB loads of Gloucester City, State Street and Federal Streets in Camden, all industrial urban locations.

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APPENDIX 1.

Table 2. PCB Congener Results for CCMUA Wastewater Sampling (pg/l)

PCB#[1]	WPFC #1			Federal Street PS			State St. PS			Baldwin PS			Gloucester I.			Cooper I.		
	WW (co)	WW (gr)	PISCES	WW (co)	WW (gr)	PISCES	WW (co)	WW (gr)	PISCES	WW (co)	WW01 (gr)	PISCES	WW (co)	WW (gr)	PISCES	WW (co)	WW (gr)	PISCES02
1	684	1390	62200	3990	3870	31300	351	94	369	202	119	4330	11600	1960	58400	71	50	1260
3	322	516	23500	2030	1490	13000	631	156	262	133	62	2860	3770	654	15900	82	47	1070
MONO	**1006**	**1906**	**85700**	**6020**	**5360**	**44300**	**982**	**250**	**631**	**335**	**181**	**7190**	**15370**	**2614**	**74300**	**154**	**97**	**2330**
4	863	1370	136000	2510	2760	15900	1700	407	1690	605	276	11700	2250	586	12600	143	103	1660
5	56	53	2170	184	134	1020	33	11	32	88	151	729	160	38	699	13	21	114
6	455	433	33200	1110	872	5890	436	134	419	171	73	3700	896	226	4190	102	57	850
7	103	96	5270	373	239	1920	64	21	71	35	17	736	282	68	1220	21	14	171
8	1490	1630	100000	4340	3580	21300	1390	423	1860	683	289	15600	2690	722	12300	434	256	3460
10	52	67	3250	194	215	1290	84	23	89	28	13	569	209	61	1470	7	5	81
11	575	675	8440	769	1130	2730	1580	408	1040	779	597	11300	941	605	5810	691	363	3660
12	164	189	11300	618	426	2240	289	92	142	127	187	1200	396	93	1140	50	47	302
14	2	2	27					2				15			8	1	1	6
DI	**3759**	**4516**	**299657**	**10098**	**9356**	**52290**	**5575**	**1522**	**5343**	**2516**	**1603**	**45549**	**7824**	**2398**	**39437**	**1462**	**867**	**10304**
16	611	770	24000	1270	1460	5100	894	272	866	377	175	7700	341	187	2770	263	148	1570
17	765	858	51100	1450	1410	5130	1210	353	976	381	175	8620	411	208	2930	270	156	1420
18	1380	1530	65500	2760	2870	10700	1870	608	1760	750	342	16600	729	408	5970	519	293	3000
19	233	335	23000	426	505	1670	889	215	545	132	65	2590	173	86	1280	61	40	383
20	1890	2380	90300	3750	3600	12200	4020	1340	2760	1040	469	21000	1460	627	7730	964	478	4330
21	1030	1260	26900	2150	2180	7390	1960	601	1440	633	284	12300	670	361	4330	597	298	2730
22	689	912	29000	1380	1410	4150	1520	449	851	425	195	7050	529	240	2520	369	191	1540
24	21	26	665	52	45	183	30	10	28	12	6	245	14	6	131	7	4	51
25	186	205	10500	269	261	996	466	137	251	76	35	2040	143	45	708	59	31	324
26	372	429	17500	674	686	2350	835	248	506	183	83	3280	235	98	1380	146	77	742
31	1830	2170	80200	3470	3400	11200	3570	1070	2220	1000	445	16800	1480	585	7310	861	460	3890
32	499	658	28700	1000	1070	2980	1130	293	659	276	121	9340	370	157	2060	179	105	905
37	373	605	16100	808	718	2420	1300	435	344	256	120	3630	387	145	1270	198	110	752
TRI	**9879**	**12138**	**463465**	**19459**	**19615**	**66469**	**19694**	**6031**	**13206**	**5540**	**2515**	**111195**	**6942**	**3152**	**40389**	**4492**	**2392**	**21637**

PCB#[1]	**WPFC #1**			**Federal Street PS**			**State St. PS**			**Baldwin PS**			**Gloucester I.**			**Cooper I.**		
40	906	1170	38900	1430	1310	3780	2220	696	403	524	251	12100	807	362	2420	480	229	1280
44	2830	2780	136000	2430	2080	6700	4000	1250	1410	1200	539	168000	1640	780	6380	1060	487	2840
45	421	439	11600	536	508	1630	893	274	327	198	101	71400	264	116	1190	158	75	488
46	105	138	4510	185	188	536	262	81	73	63	33	1880	90	41	358	50	24	166
48	329	410	11400	579	524	1650	732	216	186	186	87	2600	225	119	913	177	86	510
49	1350	1540	78800	1410	1230	3830	2440	727	630	616	288	48900	986	423	3490	519	254	1480
50	284	348	14600	373	364	1110	699	195	183	153	77	27600	244	96	966	99	52	339
52	5700	6010	425000	2970	2350	6790	4730	1400	1450	1630	744	27600	2230	1200	9380	1440	692	4020
53	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
56	675	902	27000	1040	816	2280	1740	534	204	460	206	5060	766	290	1450	376	175	794
60	331	460	13600	578	443	1350	921	311	120	246	110	2830	352	164	811	207	98	466
61	4520	4860	253000	3860	3130	9180	6370	1950	1310	2040	866	27600	3410	1520	8840	1930	857	4520
63	63	78	3320	79	70	212	152	45	23	35	17	1120	71	23	145	30	15	76
64	853	1020	42100	1020	888	2690	1680	527	344	404	189	6210	588	298	1960	396	188	1040
66	1430	1820	70400	1910	1610	4540	3300	1030	497	870	375	11000	1560	617	3280	719	332	1630
77	96	141	3240	141	115	378	410	149	33	85	45	1160	166	61	263	61	34	129
80								11								13		
81	5	7			5	19	14	5				66		3	13	3	2	
TETRA	**19898**	**22124**	**1133470**	**18541**	**15631**	**46675**	**30563**	**9401**	**7193**	**8710**	**3928**	**415126**	**13399**	**6112**	**41859**	**7718**	**3599**	**19778**
82	637	754	42800	329	224	431	833	254	89	308	116	3500	550	220	867	229	116	390
83	3600	3870	232000	1360	945	1550	3590	1180	485	1340	525	27100	3190	1110	4690	1270	556	1810
84	2170	2430	163000	803	518	919	1790	552	244	633	274	9210	1040	508	2410	635	269	1070
85	957	977	56700	462	310	572	1170	381	144	415	162	8210	905	340	1350	333	168	548
86	6780	7120	486000	1910	1290	2270	4500	1440	626	1840	732	30000	3700	1440	6630	1500	744	2850
88	744	788	47200	363	240	465	898	287	124	280	131	50800	545	234	1150	269	118	449
89	44		2550	38	28	66	77	26	8	20	9	286	34	17	78	23	9	35
90	28300	32200	2640000	2670	1730	2820	6500	2740	922	2640	1050	64900	5180	2130	9200	2320	1070	3760
92		3490	277000	488	326	488	1330	466	158	458	183	13000	1000	365	1570	402	185	634
93	21800	24800	2120000	2270	1440	2690	5340	2170	829	1830	823	62800	3080	1540	8180	1810	833	3290
105	2210	2470	164000	813	582	909	2270	745	214	903	342	10800	2440	715	2610	667	330	1010
107	278	282	19400	86	60	90	249	73	25	94	36	1040	266	73	303	69	38	114
110	14100	16100	1230000	2830	1960	2740	7990	2740	800	2880	1090	34000	6460	2250	8900	2190	1110	3650
114	123	149	10600	48	32	69	120	40	16	51	20	656	125	37	158	44	22	68

PCB#[1]	WPFC #1			Federal Street PS			State St. PS			Baldwin PS			Gloucester I.			Cooper I.		
118	7530	8340	584000	1900	1330	1940	5120	1720	579	2140	830	24800	6820	1760	6730	1650	815	2590
123	95	110	5340	74	47	70	139	39	13	63	31	629	212	55	198	49	26	112
PENTA	**89368**	**103880**	**8080590**	**16443**	**11062**	**18089**	**41916**	**14854**	**5276**	**15895**	**6354**	**341731**	**35547**	**12795**	**55024**	**13460**	**6409**	**22380**
128	3010	3510	414000	357	236	207	1530	551	63	514	190	4620	2150	329	999	306	143	332
129	64200	78300	7440000	2310	1550	1650	9660	5170	496	3110	1230	57200	12700	2000	7020	2010	1060	2560
130	1840	1980	161000	139	96	92	582	253	28	193	80	2090	789	128	435	124	57	151
132	18500	22600	2230000	821	525	593	3110	1600	169	981	373	11200	3540	657	2140	705	322	816
134	2700	2890	243000	137	88	103	451	238	29	153	60	3790	500	107	425	122	56	158
135	35200	41800	4700000	731	466	684	2940	2120	218	803	343	47400	2420	562	2210	600	324	886
136	11900	13800	1420000	317	184	291	1060	942	85	313	131	11200	877	249	927	365	127	383
137	353	329	27000	119	84	80	399	130	24	170	63	2240	757	114	408	117	55	123
141	20200	23800	2630000	423	274	378	1770	1240	98	545	217	9120	1860	340	1300	351	176	500
146	9170	10900	838000	298	212	236	1500	787	80	400	173	10600	1500	250	917	278	147	355
147	76000	90100	9530000	1820	1180	1550	7050	4770	466	2060	849	92200	6810	1380	5470	1490	753	2130
153	77800	95400	10100000	1800	1240	1510	7850	4990	487	2420	1010	50200	8960	1560	5750	1650	886	2360
156	3840	4150	331000	257	167	158	1050	444	40	404	158	3980	1820	285	829	267	137	299
158	5600	6420	488000	231	156	169	950	506	47	322	124	4390	1310	210	748	204	102	262
167	1360	1460	116000	78	51	50	370	168	16	124	49	1400	544	84	258	77	39	86
HEXA	**331673**	**397439**	**40668000**	**9838**	**6509**	**7751**	**40272**	**23909**	**2345**	**12512**	**5050**	**311630**	**46537**	**8255**	**29836**	**8666**	**4383**	**11401**
170	34000	48300	2660000	403	243	307	2770	2000	69	724	289	20400	2100	354	1050	310	219	442
171	9810	13300	925000	131	78	98	854	645	24	219	82	5680	606	105	351	107	67	145
172	6080	8980	674000	71	47	57	581	383	15	129	57	4250	362	62	204	56	39	79
174	43600	62700	3740000	466	280	399	3060	2490	90	745	293	19400	2010	388	1330	359	224	486
176	5250	6760	587000	65	40	61	342	303	17	87	39	2630	249	52	178	55	33	78
177	22400	30000	1820000	265	149	210	1750	1380	53	406	151	11100	1120	215	689	195	127	273
178	8000	10100	698000	95	62	92	611	496	27	145	61	10200	414	88	342	86	52	123
179	17900	23500	1700000	227	133	214	1190	1030	56	285	123	18400	898	194	653	185	107	267
180		134000	8480000	1020	638	820	6900	5060	190	1680	657	60100	4940	906	2990	793	552	1180
181	61	80	8280	4	3		22	10		7	3	353	32	4	14	5	3	4
183	28700	39000	2530000	334	212	302	2100	1730	74	535	210	17200	1430	299	1040	282	179	428
187	50300	71900		592	376	547	3860	2990	143	895	384	42400	2670	564	1990	503	307	717
189	982	1110	93400	13	9	12	89	66		24	9	789	81	13	34	12	8	16
190	7420	9670	591000	81	49	72	558	442	17	145	61	5380	384	77	260	63	45	105

PCB#[1]	WPFC #1			Federal Street PS			State St. PS			Baldwin PS			Gloucester I.			Cooper I.		
191	1370	1800	147000	17	10	13	115	84		31	12	936	78	15	45	13	10	20
HEPTA	**235873**	**461200**	**24653680**	**3785**	**2328**	**3203**	**24803**	**19109**	**774**	**6057**	**2431**	**219218**	**17374**	**3336**	**11171**	**3024**	**1972**	**4363**
194	21100	26900	1910000	191	124	215	1530	1250	34	393	151	22200	1170	264	641	164	113	219
195	8340	11000	843000	80	47	78	556	485	14	147	56	8340	352	79	223	60	41	84
196	11000	15300	1830000	114	76	108	874	658	20	217	85	9730	631	134	364	101	69	124
197	3630	5930	441000	50	38	38	332	225	7	73	37	2810	282	50	122	43	24	42
198	23600	31200	2530000	280	172	310	2110	1530	56	489	200	22200	1880	399	1050	253	165	323
201	2690	3470	352000	37	27	35	236	179	6	59	22	2380	198	43	125	38	21	43
202	4490	5820	402000	71	52	70	523	334	15	139	66	4760	395	98	244	81	47	77
203	13800	18300	1960000	167	111	149	1290	905	27	313	123	12000	1140	254	559	154	110	178
204	2	3		0	0		2	1		1	0	12	1	1	2	1	0	
205	1060	1210	97500	10	6		72	66		18	6	1000	44	10	30	9	6	10
OCTA	**89712**	**119133**	**10365500**	**1000**	**653**	**1003**	**7525**	**5632**	**181**	**1849**	**746**	**85432**	**6093**	**1333**	**3360**	**902**	**595**	**1100**
206	5880	7140	492000	129	98	297	1450	686	24	292	117	5590	1480	299	474	130	86	137
207	768	920	76300	17	12	30	162	80		33	14	834	141	31	62	17	11	17
208	1170	1520	107000	45	36	139	524	211	10	101	41	1300	380	79	162	47	27	46
NONA	**7818**	**9580**	**675300**	**190**	**145**	**466**	**2136**	**977**	**35**	**426**	**172**	**7724**	**2001**	**409**	**698**	**193**	**124**	**200**
209	189		10900			349		369	18			718		111	211	72	44	49
DECA	**189**		**10900**			**349**		**369**	**18**			**718**		**111**	**211**	**72**	**44**	**49**
TOTAL	**789081**	**1131914**	**86430812**	**85373**	**70660**	**240420**	**173466**	**81870**	**34994**	**53839**	**22979**	**1545154**	**151088**	**40458**	**296178**	**40107**	**20460**	**93516**

*** PCB# = IUPAC or Congener Number; WWCO = Wastewater Composite sample; WWGR = Wastewater Grab sample; NA = Not Analyzed**