AMBIENT AIR MONITORING FOR DIOXINS, FURANS, POLYCHLORINATED BIPHENYLS, AND POLYBROMINATED DIPHENYL ETHERS IN URBAN LOCATIONS OF CALIFORNIA

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ABSTRACT

Very little was known until recently about ambient air concentrations of dioxins and related compounds in California. Most of the dioxin air monitoring data gathered until now was from focused, short-term studies, or from sparse monitoring in rural areas. The California Ambient Dioxin Air Monitoring Program (CADAMP) was initiated by the California Air Resources Board (ARB) in 2001 to answer questions about dioxin ambient air exposure in urban areas, and to expand the list of analytes to a family of related, harmful compounds. The chemical groups included in CADAMP are polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), dioxin-like polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs). CADAMP was conducted in the South Coast and San Francisco Bay areas from 2002 through 2004. Ambient air measurements of PCDDs, PCDFs, PCBs, and PBDEs will be evaluated to better understand the distribution, composition, and risk posed by the wide range of chemical congeners in each family of compounds. CADAMP is modeled, in part, after USEPA's National Dioxin Air Monitoring Network (NDAMN), using similar sampling and analytical protocols. It is different, however, in that it has an urban focus while the NDAMN program conducts monitoring in rural areas to study pathways by which dioxins enter the food chain. In addition to monitoring in urban areas, CADAMP is unique given the inclusion of ambient sampling for PBDEs, a group of contaminants of emerging public concern and legislative action. This paper outlines the sampling protocols for collection of medium air volume samples (20-24 days per sample at 0.24 cubic meters per minute), and outlines the comprehensive field and laboratory QA/QC measures that were used to obtain reliable quantitative results at extremely low concentrations (femtograms per cubic meter). This paper presents the dioxin, furan and PCB results from air monitoring conducted during 2002 and 2003. The data will be discussed in terms of overall concentrations as well as temporal, seasonal and geographical trends. The PBDE results are still under evaluation and will be reported in the near future.

INTRODUCTION

The California Air Resources Board (ARB) recently completed its third year of a comprehensive ambient air quality monitoring and testing program to collect data for polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and dioxin-like polychlorinated biphenyls (PCBs). The California Ambient Dioxin Air Monitoring Program (CADAMP) was conducted in two large urban regions of California over an initial two-year period. Funding was extended for an additional year using the same configuration and number of samplers for 2004 resulting in three full years of monitoring. Beginning in the summer of 2003, and continuing through 2004, monitoring included polybrominated diphenyl ethers (PBDEs or flame retardants). The results will be evaluated to understand the distribution, composition, and risk posed by the wide range of chemical congeners in each family of compounds.

The specific objectives of CADAMP are to:

- Assess airborne concentration of dioxins, furans, and dioxin-like PCBs in populated areas in California potentially impacted by emissions from stationary and mobile sources;
- Evaluate this information and determine the risk posed by exposure to ambient air concentrations of these compounds; and
- Provide additional information for the California Children's Environmental Health Protection Act (SB25, Escutia, 1999) monitoring program by using the same sampling sites.

CADAMP is modeled, in part, after the U.S. Environmental Protection Agency's (US EPA) National Dioxin Air Monitoring Network (NDAMN) and uses similar sampling and analytical protocols. CADAMP, however, has an urban focus while the NDAMN program focuses in rural areas to study pathways by which dioxins enter the food chain. In addition, CADAMP includes limited ambient sampling for PBDEs.

CADAMP SITES

CADAMP air samples were collected at five urban sites in the San Francisco Bay Area, and four urban sites in the South Coast Air Basin. Sites were chosen based on several factors including proximity to suspected dioxin sources, a site history of elevated concentrations of criteria, toxic and related pollutants, location of SB25 (Children's Environmental Health Protection Act) sites, and location of existing ARB or local air district monitoring sites. Monitoring in the Bay Area was conducted in San Jose, Oakland, Richmond, Crockett, and Livermore with the cooperation of the Bay Area Air Quality Management District. Sites in the South Coast area were located in Boyle Heights, Wilmington, Reseda, and Rubidoux and were supported by staff from the South Coast Air Quality Management District. CADAMP began in the Bay Area and South Coast in December 2001 and continued through 2004. CADAMP monitoring benefited from two rural NDAMN monitoring sites in California. The first, Fort Cronkhite, was an NDAMN background site on the coast north of San Francisco that was intended to measure dioxin

levels in onshore airflow from the Pacific Ocean. The other NDAMN site was located in an agricultural area approximately 20 miles south of Sacramento at Rancho Seco Park.

SAMPLING AND ANALYTICAL METHODS

Sampling

USEPA Method TO-9A was used as the basis for the ambient air sampling and analytical procedures for CADAMP. The samplers collected atmospheric particulate material on a quartz fiber filter (QFF) while vapor-phase constituents passed through the QFF and impinged on a pre-cleaned polyurethane foam plug (PUF) inside a glass cartridge. One of the major challenges of the program was finding PUF material that had not been treated with flame retardant. Standard laboratory cleaning procedures for dioxins/furans were not effective in removing PBDEs. The laboratory experimented with cleaning techniques, but found that the effort needed to sufficiently remove PBDE degraded the PUF making it unusable for sampling. Once a manufacturer was found that could deliver "FR-free" PUF, the laboratory performed an extensive cleaning procedure to get background levels under the target of 20 picograms per sample for most congeners. BDE-209 was often present in the quality control checks performed on cleaned PUF that might affect field and laboratory blanks, but preliminary data indicate that levels were orders of magnitude lower than levels detected in field samples.

The PUF was augmented with XAD-2 resin between two portions of the PUF, forming a PUF-XAD-PUF sandwich. The XAD-2 resin facilitated the capture of PCB congeners. The samplers were operated in the standard configuration described in USEPA Method TO-9A, but the sampling period was extended to cover an entire month (576 hours or 24 days out of every 28 days). This resulted in thirteen 28-day sampling moments per year. QFFs were replaced weekly to prevent overloading the filter with particulate, thereby maintaining a relatively constant flow rate. The PUF-XAD-PUF sandwich remained in place for the four weeks of the sampling moment.

Analysis

The four QFFs and one PUF sandwich were combined and extracted as a single sample per USEPA Method TO-9A. The single extract was split and used for analysis of dioxins, furans, and fourteen dioxin-like PCBs by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS). A portion of the extract was retained to archive and use as backup, if needed. Over 500 samples have been collected and analyzed using Methods TO-9A and 1668A. Selected samples were also analyzed for 44 PBDE congeners using USEPA Draft Method 1614 and the PCB fraction of the extract.

The detection limit of approximately 0.2 femtograms per cubic meter (fg/m^3) for 2,3,7,8-TCDD was achieved by using the extended sampling period. The low detection limits are necessary because the concentrations of many of the PCDD, PCDF, and PCB congeners of concern are normally detected in ambient air in very low concentrations. Since non-detects are seldom observed using the extended sampling approach, the low detection limits

provide for a more accurate determination of toxicity equivalence (TEQ) relative to higher detection limit methods. A contract laboratory specializing in the analyses of dioxins/furans and PCBs analyzed the samples for ARB.

Quality Assurance

A comprehensive plan for field and laboratory quality assurance (QA) was developed for CADAMP. The QA plan includes details on sampler flow rate verification, collocated and field blank samples, field surrogates spiked into each PUF cartridge prior to sampling, laboratory control samples, laboratory procedural blanks, and all other performance checks required by Method TO-9A. The QA audit program developed by the ARB included field flow rate and systems audits at each site, a laboratory systems audit, and performance evaluation samples submitted to both the State laboratory and the USEPA NDAMN laboratory to evaluate comparability between programs. Parallel sampling with a CADAMP sampler was also performed at NDAMN's Fort Cronkhite site. All aspects of the field operations and QA plan can be found at ARBs dioxin site at http://www.arb.ca.gov/aaqm/qmosopas/dioxins/dioxins.htm.

PROGRAM CHANGES

Since the inception of CADAMP, several changes were made to improve the quality and quantity of data collected.

January 2003

A Sacramento sampling site and a collocated sampler at the Oakland sampling site were added to the network resulting in twelve samplers operating each sampling moment.

May 2003

Sampling for PBDEs began at six of the urban CADAMP monitoring locations (San Jose, Oakland, Richmond, Boyle Heights, Wilmington, and Rubidoux). Sampling continued through December 2004.

June 2003

Electronic flow rate data-loggers were added to the samplers to supplement the Dickson chart recorders and provide a more accurate recording of flow rates. Prior to using data-loggers, if the sampler QA measures were within specifications, the average flow rates were assumed to be 0.24 cubic meters per minute for volume calculations. With data from the loggers, average flow rates were calculated based on actual hourly readings.

A CADAMP sampler was collocated at Fort Cronkhite with the NDAMN sampler for QA purposes. It was in operation for three sampling moments.

January 2004

Sampling days were reduced from six days per week to five days per week. This change reduced particle loading on the QFFs and allowed the sampler operators more flexibility in

performing the filter change-outs. Previous results obtained in the CADAMP showed that the reduction in sampling time would not affect the percentage of non-detects in the samples. Reducing the volume collected also reduced matrix interferences encountered during sample analyses.

December 2004

All samplers were shut down after the PUF and QFF retrieval. Samplers were removed from all sites except for those at Livermore in the Bay Area and at Rubidoux in the South Coast.

January 2005

The network was reconfigured to acquire information on ambient dioxin levels in an area of the state not originally part of the CADAMP monitoring. Sampling resumed with the network that includes a single sampler in the Bay Area, one in the South Coast, and two in Fresno County in the San Joaquin Valley. One of the Fresno sites will be in an area remote from Fresno and allow for comparisons of high-population, industrialized urban areas versus non-urban areas in the Valley. The 2005 CADAMP network is scheduled to run through April 2006.

RESULTS

The results of this study are presented as total toxicity equivalence (TEQ). The TEQ is reported in units of femtograms per cubic meter (fg/m^3), and is the sum of the individual TEQs for each dioxin, furan, and PCB congener per sample unless otherwise specified. California officially adopted the World Health Organization 1997 Toxicity Equivalence Factor (WHO 97 TEF) values in 2003. The WHO 97 TEF values were also used in NDAMN allowing for comparisons between the networks.

The PBDE results from 2003 and 2004 are currently under evaluation and will be reported in the future on the ARB webpage.

2002 Results

Eighty-four percent of the field samples collected were valid. Fifty-three out of 60 (88 percent) from the Bay Area and 48 out of 60 (80 percent) from the South Coast were valid.

Average TEQ results for all sites in 2002 ranged from 13 to 43 fg TEQ/m^3 for dioxins and furans with a statewide average of 24 fg TEQ/m^3. For PCBs, average TEQ results ranged from 1.9 to 10 fg TEQ/m^3 with a statewide average of 5.8 fg TEQ/m^3. Annual averages were calculated only for those sites meeting strict completeness criteria as described in the CADAMP QAPP to ensure a representative annual average concentration. San Jose, Rubidoux, and Reseda were excluded from the annual averages for 2002 for that reason.

Field Blank Results

Field blanks were collected on a rotating basis during 2002 at all of the sites. One field blank was collected each sampling moment at one Bay Area site and at one South Coast site. Twenty-one out of 24 (88 percent) field blanks collected were valid. Field blank TEQ results ranged from 0.26 to 1.2 fg TEQ/m^3 for dioxins/furans. The Bay Area average was 0.5 fg TEQ/m^3 and 0.4 fg TEQ/m^3 for the South Coast. For PCBs, the field blank TEQ results ranged from 0.01 to 0.06 fg TEQ/m^3. The Bay Area average for PCBs was 0.03 fg TEQ/m^3 and 0.04 fg TEQ/m^3 for the South Coast.

Bay Area Sites

In the Bay Area, the concentrations ranged from 7.5 to 191.1 fg total TEQ/m^3. The lowest concentration of 7.5 fg TEQ/m^3 was observed during the June 6, 2002, sampling period at Livermore. The highest concentration of 191.1 fg TEQ/m^3 was observed during the January 17, 2002, period at Livermore. Staff is investigating why this TEQ was significantly higher than other TEQs during this sampling moment. There were no similarly high concentrations at Livermore during 2003. The PCB contribution to the total TEQ ranged from less than one percent to 58 percent. San Jose samples did not meet criteria to calculate an annual average for 2002.

Table 1. 2002 Bay Area Annual Averages (fg TEQ/$m^{3)}$

	Oakland	Crockett	Richmond	Livermore	San Jose
Dioxin/Furan TEQ Range	10-66	6.1-27	6.5-31	6.4-190	13-63
Dioxin/Furan Annual Average	27	13	17	43	Not valid
PCB TEQ Range	4.2-12	0.5-7.2	3.3-9.0	1.0-3.3	2.6-4.8
PCB Annual Average	7.4	3.0	5.9	1.9	Not valid
Total TEQ (Dioxin/Furan TEQ + PCB TEQ)	35	16	23	45	NA

South Coast Sites

In the South Coast Air Basin, the concentrations ranged from 10.6 to 167.1 fg total TEQ/m^3. The lowest concentration of 10.6 fg TEQ/m^3 occurred during the May 16, 2002, sampling period at Wilmington. The highest concentration of 167.1 fg TEQ/m^3 was during the August 29, 2002, period at Reseda. In the South Coast the PCB contribution to the total TEQ ranged from three percent to 50 percent. Rubidoux and Reseda samples did not meet criteria to calculate annual average for 2002.

Table 2. 2002 South Coast Annual Averages (fg TEQ/m^3)

	Boyle Heights	Boyle Heights Collocated	Wilmington	Rubidoux	Reseda
Dioxin/Furan TEQ Range	10-33	10-33	7.8-62	8.6-69	9.4-156
Dioxin/Furan Annual Average	21	21	26	Not valid	Not valid
PCB TEQ Range	5.1-21	5.1-19	2.8-15	1.2-6.3	2.5-12
PCB Annual Average	10	10	6.8	Not valid	Not valid
Total TEQ (Dioxin/Furan TEQ + PCB TEQ)	31	31	33	NA	NA

Precision Results

Precision was evaluated using the average relative percent difference (RPD) between collocated sample pairs and between laboratory control sample pairs (LCS). The results were excellent. Seven of nine collocated sample pairs collected in the South Coast at Boyle Heights had valid results for 2002. Average RPD for individual dioxin/furan congener concentrations was 10 percent and average RPD for individual PCB congener concentrationss was 14 percent. The average TEQ RPD was 5.9 percent for dioxins/furans and 15.3 for PCBs. The yearly average RPD for dioxins/furan concentrations in the LCS pairs was 4.9 percent and 3.5 percent for PCBs.

2003 Results

Ninety-three percent of the field samples collected in 2003 were valid. Seventy-three out of 78 (94 percent) from the Bay Area, 60 out of 65 (92 percent) from the South Coast, and 12 out of 13 (92 percent) from Sacramento were valid.

Average TEQ results for all sites in 2003 ranged from 18 to 26 fg TEQ/m^3 for dioxins and furans with a statewide average of 23 fg TEQ/m^3. For PCBs, average TEQ results ranged from 2.2 to 10 fg TEQ/m^3 with a statewide average of 6.1 fg TEQ/m^3.

Field Blank Results

Field blanks were similarly collected during 2003 at all of the sites on a rotating basis. One field blank was collected each sampling moment at one Bay Area site and at one South Coast site. Field blank TEQ results ranged from 0.28 to 1.6 fg TEQ/m^3 for dioxins/furans. Both the Bay Area and South Coast averages were 0.5 fg TEQ/m^3. For PCBs, the field blank TEQ results ranged from 0.01 to 0.06 fg TEQ/m^3. Both the Bay Area and South Coast averages for PCBs were 0.03 fg TEQ/m^3.

Bay Area Sites

In the Bay Area, concentrations ranged from 5.9 to 72.3 fg total TEQ/m^3. The lowest concentration of 5.9 fg TEQ/m^3 was observed during the April 10, 2003, sampling period

at Crockett. The highest concentration of 72.3 fg TEQ/m^3 was observed during the January 16, 2003, period at San Jose. The PCB contribution to the total TEQ ranged from two percent to 61 percent, similar to the 2002 results. Crockett samples did not meet criteria for calculating an annual average for 2003.

Table 3. 2003 Bay Area Annual Averages (fg TEQ/m^3)

	Oakland	Oakland Collocated	Crockett	Richmond	Livermore	San Jose
Dioxin/Furan TEQ Range	11-53	11-48	4.4-22	6.6-44	7.4-65	7.3-69
Dioxin/Furan Annual Average	26	24	Not valid	19	26	22
PCB TEQ Range	4.0-14	3.6-15	1.2-6.0	4.0-19	1.0-4.0	1.5-5.2
PCB Annual Average	8.5	8.6	Not valid	9.2	2.2	3.2
Total TEQ (Dioxin/Furan TEQ + PCB TEQ)	32	33	NA	28	28	25

South Coast Sites

In the South Coast, the concentrations ranged from 8.7 to 73.6 fg total TEQ/m^3. The lowest concentration of 8.7 fg TEQ/m^3 was observed during the April 10, 2003, sampling period at Reseda. The highest concentration of 73.6 fg TEQ/m^3 was observed during the November 20, 2003, period at Rubidoux. In the South Coast the PCB contribution to the total TEQ ranged from three percent to 51 percent, showing little change from 2002.

Table 4. 2003 South Coast and Sacramento Annual Averages (fg TEQ/m^3)

	Boyle Heights	Boyle Heights Collocated	Wilmington	Rubidoux	Reseda	Sacramento
Dioxin/Furan TEQ Range	9.4-37	8.7-36	12-53	8.6-71	6.4-37	7.1-65
Dioxin/Furan Annual Average	21	21	26	26	18	26
PCB TEQ Range	5.5-13	5.8-16	3.2-9.3	2.2-8.2	1.5-11	1.9-12
PCB Annual Average	10	10	6.2	4.3	5.4	6.0
Total TEQ (Dioxin/Furan TEQ + PCB TEQ)	31	32	32	30	24	32

Precision Results

Collocated samples, for total precision (field and laboratory), were collected at two sites in 2003, Oakland in the Bay Area and Boyle Heights in the South Coast. For the thirteen sampling moments, there were ten valid pairs collected from the Bay Area and eight valid pairs collected from the South Coast. Average RPD for individual dioxin/furan congener concentrations was again excellent, 10.3% at Oakland and 3.0% at Boyle Heights. The average RPD for individual PCB congener concentrations was 8.3% at Oakland and 4.5% at Boyle Heights. The average TEQ RPD for dioxins/furans for the Oakland site was 7.9% and 7.6% for PCBs. The average TEQ RPD for the Boyle Heights site was 4.9% for dioxins/furans and 5.4% for PCBs. The yearly average RPD in the LCS pairs was 3.8% for dioxins/furan concentrations and 2.0% for PCBs.

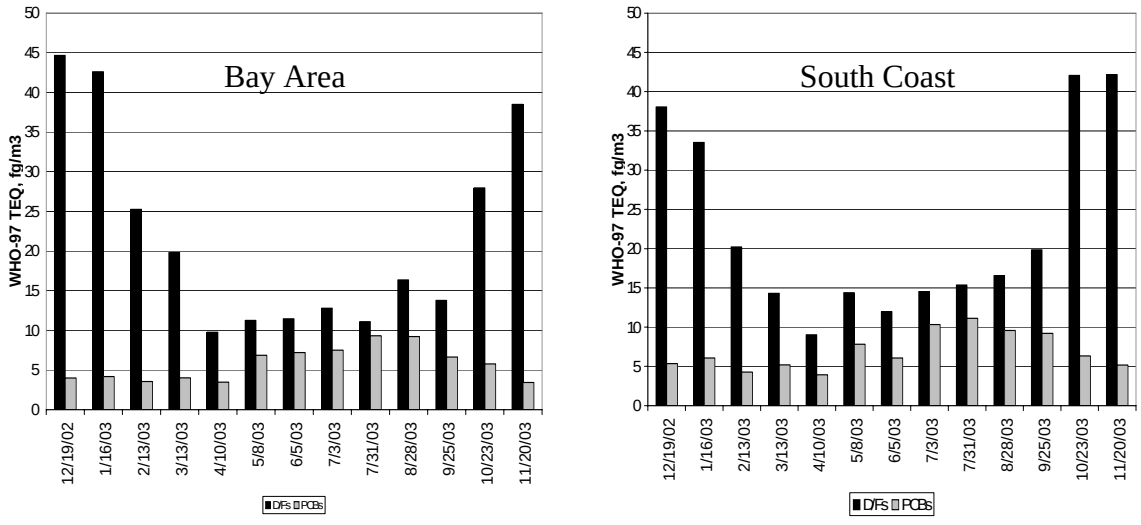
2004 Results

Results for 2004 are currently undergoing review and validation by ARB staff. Results will be posted on ARB's dioxin web site (www.arb.ca.gov/aqa/cadamp.html) and will include dioxins, furans, PCBs, and PBDEs.

Monitoring Data Summary

CADAMP annual averages for 2002/2003 ranged from 13 to 43 fg TEQ/m^3 for dioxins/furans and 2 to 10 fg TEQ/m^3 for PCBs. The 2002 statewide dioxin/furan average was 24 fg TEQ/m^3 and 5.8 fg TEQ/m^3 for PCBs. The 2003 statewide dioxin/furan average was 23 fg TEQ/m^3 and 6.1 fg TEQ/m^3 for PCBs. Both dioxins/furans and PCBs show seasonal patterns with dioxins/furans higher in the winter and lower in the summer and PCBs lower in the winter and higher in the summer. Patterns for the Bay Area and the South Coast are similar, as shown in Figure 1.

Figure 1. 2003 TEQ Averages



Data Comparisons

It is appropriate to make direct comparisons using data from the two CADAMP urban areas, and between CADAMP and NDAMN. Inconsistencies in network design between earlier studies in California, however, make those comparisons problematic. The fundamental differences in the latter included shorter sampling duration, inconsistent toxicity equivalence factors (TEFs), higher detection limits, and different sampling locations. A literature search provided few long duration sampling studies conducted in the U.S. for comparison and included only limited information. Various TEF schemes were used among the studies for calculating TEQ making comparisons impossible without raw data. Studies did not always include how detection limits were handled in TEQ calculations. Some used ½ the detection limit for non-detects while others used zero.

Elevated detection limits for non-detects were also a problem that resulted in elevated TEQ. (CADAMP negated this issue with long duration sampling resulting in few non-detects.) Not all studies described expected sources of dioxin and did not detail whether the samples were collected in urban, rural, or remote locations. For studies that did provide adequate information for comparison, results are presented in Table 5.

With the understanding that most of the existing dioxin data represent rural locations, it is not surprising that CADAMP dioxin/furan results are higher than other ambient air studies conducted in the United States. CADAMP results are 15 times higher than remote sites in NDAMN, eight times higher than at the NDAMN background site at Fort Cronkhite, and 1.8 times higher than NDAMN rural sites. On average, they are also 1.6 times higher than other U.S. urban results.

Table 5. U.S. TEQ Comparisons

	Average D/F fg TEQ/m^3	Percent of CADAMP All Sites D/F Average TEQ[4]	Average PCBs fg TEQ/m^3	Percent of CADAMP All Sites PCB Average TEQ[4]
CADAMP Bay Area[1]	23		4.8	
CADAMP South Coast[1]	23		6.6	
CADAMP Sacramento[1]	26		6.0	
CADAMP All Sites[1]	**23**		**5.6**	
NDAMN[2] Remote	1.5	7%	0.2	4%
NDAMN[3] Fort Cronkhite	2.9	13%	0.4	7%
NDAMN[2] Rural	13	57%	1.0	18%
NDAMN[2] Washington, DC	14	61%	2.6	46%
EPA[3] Calcasieu Parish, LA	14	61%	1.4	25%

1-Average of 2002/2003 valid annual averages
2-2000 and 2001 data
3-2001 data
4-TEQ expressed as percent relative to CADAMP All Sites TEQ

2005 MONITORING

CADAMP monitoring is ongoing but has been revised for 2005. The reduced network will include two urban sites that have been in operation since 2002, and two San Joaquin Valley sites, one urban and one non-urban. The urban sites are Livermore, in the San Francisco Bay Area, Rubidoux, in the South Coast Air Basin, and Fresno in the San Joaquin Valley. The non-urban comparison site in the San Joaquin Valley is scheduled to begin in April. The urban sites are intended to provide additional data on urban ambient concentrations of dioxins, furans, dioxin-like PCBs, and flame-retardants. The monitoring at a non-urban site will allow comparison with Fresno and will provide unique information on PBDEs in a California rural area. Samples from the non-urban site are expected to have similar concentrations as NDAMN's rural sites but may provide information regarding potential emission transport from urban to rural areas. Monitoring at the four sites will continue for one year. Each sample will represent 20 out of 28 days per sampling moment. Sampling began January 13, 2005, and will continue through April 2006.

ARB CADAMP DATABASE

ARB created a database to store and access all field and laboratory data associated with CADAMP. The database programming performs automated field and laboratory data quality control checks, volume calculations, unit conversions, and TEQ calculations. The public has access to individual sample results contained in the database via the ARB internet pages at www.arb.ca.gov/aqa/cadamp.html. Data can be viewed by site and sampling moment as congener concentrations and TEQ. Regional and yearly averages can be accessed and data can be downloaded to an excel file. The database and web site will be regularly updated with data from the 2004 and 2005 monitoring as it is reviewed and validated.

CONCLUSIONS

With the successful collection of three full years of quality data, evaluation of that data is now underway. The timing of the collection of the CADAMP data will allow for comparisons of dioxin concentrations prior to and after implementation of regulatory controls including the recent California ban on burn barrels, diesel regulations, and the 2008 California ban on flame retardants. Congener profiles will be evaluated to identify current, potential, and reservoir emission sources.

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REFERENCES

1. Refer to http://www.arb.ca.gov/aaqm/qmosopas/dioxins/dioxins.htm for the following CADAMP documents and information:
   The California Ambient Dioxin Air Monitoring Program Quality Assurance Project Plan;
   The Field Operation of the California Ambient Dioxin Air Monitoring (CADAMP) Sampling Network;
   The Standard Operating Procedures for Andersen Instruments Poly-Urethane Foam (PUF) Sampler-Special;
   A link to detailed descriptions of the network monitoring sites;
   The sampling schedules;
   A link to the monitoring results; and
   A program overview with sampling results presented in powerpoint format.
2. U.S. EPA Compendium Method TO-9A Determination of Polychlorinated, Polybrominated and Brominated/Chlorinated Dibenzo-p-Dioxins and Dibenzofurans in Ambient Air, January 1999
3. U.S. EPA Method 1668A, Revision B: Chlorinated Biphenyl Congeners in Water, Soil, Sediment, and Tissue by HRGC/HRMS, December 1999
4. U.S. EPA Method 1613 Revision B Tetra-Through Octa-Chlorinated Dioxins and Furans by Isotope Dilution HRGC/HRMS, October 1994
5. U.S. EPA Method 1614 Brominated Diphenyl Ethers in Water, Soil, Sediment and Tissues by HRGC/HRMS DRAFT August 2003
6. National Dioxin Air Monitoring Network http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=22423, http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54886 (Exposures Item 7)
7. Ambient Air Sampling for Dioxins, Furans and Coplanar PCBs in An Urban Industrialized Corridor in Calcasieu Parish, Louisiana www.deq.state.la.us/evaluation/calcasieu/index.htm