BACKGROUND DOCUMENT
REPORT ON REVISIONS TO

5TH EDITION AP-42

Section 1.6

Wood Residue Combustion In Boilers

Prepared for:

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1.0 INTRODUCTION

This report documents the revision to Section 1.6, Wood-fired Boilers, published in Supplement G of the 5th Edition of AP-42, Compilation of Air Pollutant Emission Factor. The old Section 1.6 was published in February 1999 and based largely on the combustion of green wood with moisture contents greater than 20%. The last update of emissions factors was August 1982. When data became available for dry wood combustion (<20% moisture) a revised Section 1.6 released as draft in September 1999. The public review of the September 1999 draft brought to light additional data which have been used to finalize this update of the February 1999 (Supplement E) Section 1.6 for wood-fired boilers. See Appendix A for summaries of the public comments. The major ways this revised Section 1.6 differs from the previous version include the following:

- Separate PM and NO_x emission factors are provided by dry wood and wet wood combustion.
- All emission factors have been converted to units of lb/MMBtu.
- PM factors are specified by fuel type and control device type but not by boiler type.
- NO_x, SO_2, and CO factors are specified by fuel type and not by boiler type.
- Additional toxic emission factors have been added.
- The general quality ratings for PM factors are higher than before.

Section 2 of this report describes the references used for emissions data. Section 3 describes how emission factors were calculated from the emissions data. Section 4 describes how the new factors are grouped (fuel type, control device type, etc.). Section 5 lists the references used to develop the new factors. Section 6 includes the revised Section 1.6. In addition to this report, there are electronic databases available on the web (http://www.epa.gov/ttn/chief) that contain the data used in this update. The procedures that

EPA followed to develop these emission factors can be found on line at ((http://www.epa.gov/ttn/chief) under the title “Procedures for Preparing Emission Factor Documents.”

2.0 SOURCES OF EMISSIONS DATA

The emissions data used to develop the revised emission factors for wood fired boilers were obtained from seven primary sources. These sources are described below.

- North Carolina Department of Natural Resources (NCDENR): NCDENR provided six emissions test reports from facilities that combust dry wood. They also provided 32 filterable particulate matter emissions factors summarized from the permit files of 17 facilities in North Carolina that combust dry wood.

- EPA's project file for AP-42 Section 1.6: Test reports used to develop the old Section 1.6 emission factors and the Background Information Document (5^{th} Edition, Supplement E) were used to develop the revised factors. These reports were from facilities that combust wet wood. Data from these documents were extracted and included with data from documents not previously used.

- American Furniture Manufacturers' Association (AFMA): AFMA provided two test reports containing data from four facilities that burn dry wood.

- EPA's Stack Test Information Retrieval System (STIRS): Test reports in STIRS from facilities that combust wood were identified and used to develop emission factors. These reports included data from facilities that combust wet wood and from facilities that combust dry wood.

- EPA's Emissions Standards Division (ESD) Industrial Combustion Coordinated Rulemakings (ICCR) Emissions Test Database: Records in the database containing data from facilities that combust wood (wet or dry) were extracted and used to develop emission factors.

- Oregon Department of Environmental Management: Oregon provided a database of test results (162 wood-fired boiler test reports). These reports included facilities that combust wet wood.

- U.S. EPA Control Technology Center (CTC): 33 test reports for CO, NO_x and SO_2 were extracted and included with the inventory.

The process data extracted from each reference and used to characterize the emission factors are summarized in electronic databases that serve as a companion to this report.

3.0 EMISSION FACTOR DEVELOPMENT

3.1 Emissions Data

Emissions data were extracted from the information sources summarized in Section 2 and entered into an electronic database. Data from individual test reports and other hardcopy sources were extracted and entered manually. Data from the ICCR and Oregon emissions test database was extracted and entered electronically. All test data were rated either "A" or "B". Criteria for assigning Data Quality Ratings can be found in EPA's procedure document for preparing emission factor entitled *Procedures for Preparing Emission Factor Documents.* This document is available online (www.epa.gov/ttn/chief).

Data which were considered incomplete were deleted. Test data were deleted where no unit subtype was reported, no stack oxygen (O_2) data was reported, no process rate reported, and/or where a test report was missing both pollutant concentration and corrected concentration. Further, records were deleted from the data set where multiple process rates were reported, and all records for the pollutant Opacity were deleted. Where it was available, the raw or directly measured emissions data was entered into the database. Processed emissions data, such as emission rates (pounds per hour) or emission factors (pounds per ton), were used only when they were the only data provided. In the case of ICCR data, the processed emission data were extracted along with the raw data, from which they were calculated.

Process data were used to characterize the emission sources and resulting emissions factors. The fuel type, combustor firing configuration, and emissions controls were identified for all data where sufficient information was provided. Fuel types were characterized as:

- Bark;
- Combined Bark/Wet Wood;
- Dry Wood (less than 20% moisture content); and

- Wet Wood (20%, or greater, moisture content).

Where the fuel type and fuel moisture content were not specifically described, the facility name and other information was used to characterize the fuel as wet wood or dry wood.

Reported descriptions of combustor firing configurations were used to characterize the combustors as one of the following:

- Dutch Ovens and Fuel Cells;
- Stokers, (including both spreader and mass feed);
- Fluidized Bed Combustion (FBC);
- Suspension Burners;
- Coen Combustor; and
- Not Provided- no description provided.

Reported descriptions of control devices in use at the time of the emissions test were used to characterize devices as follows:

- Mechanical Collectors- includes devices described as cyclones, single cyclones, multiple cyclones, and multiclones;
- Electrostatic Precipitators (ESP);
- Fabric Filters- includes baghouses;
- Wet Scrubbers;
- Oxygen Trim System/Opacity Monitor;
- Uncontrolled- Includes devices described as No Equipment, Breslove Separators, Breslove Separators with Reinjection, and Mechanical Collectors for Reinjection.
- Not Reported- The control device was not described.

The EPA conducted detailed analyses to determine whether or not the new emission data sets indicated emission sources should continue to be grouped the same as they were for the Supplement E edition, or whether they indicated that new emission source grouping were warranted. The EPA analyzed the data by separating each data set by boiler type, fuel type, fuel species, control device, moisture content and pollutant. Each data set was analyzed by plotting onto graphs, and comparing to the old (2/99) AP-42 data set. Any outlier data points were investigated by reviewing the original test report for any suspect test method, fuel type or sample error, that would invalidate the data point. The EPA determined that 5 boilers were burning non-representative wood fuels and therefore the test reports were deleted from the database. The non-representative wood fuels included urban wastes, agricultural wastes, flakeboard and finishing wastes. The following is a list of these test reports and boiler identification numbers:

- Evaluation Test On Twin Fluidized Bed Wood Waste Fueled Combustors Located in Central California. Test Report No. C-87-042. California Air Resources Board, Sacremento, Ca. February 7, 1990. B88
- Test Report Prepared For American Furniture Manufacturing Association. Air Monitoring Specialists, Inc. December, 1996. B63
- Evaluation Test On A Wood Waste Fired Incinerator At Pacific Oroville Power, Inc. Test Report No. C-88-050. California Air Resources Board, Sacremento, Ca. May 29, 1990. B93
- Source Test Report for Wood-Mode, Inc. located in Kreamer, Snyder County, Pennsylvania. August 1996. B141

After this analysis was complete, it was determined in some cases additional factors were needed while other pollutant categories could be combined. The specific analysis process for each pollutant is described in the following sections.

3.2 Emission Factor Calculations

All raw emissions data, if valid, were converted from standard concentrations of pounds of pollutant per dry standard cubic feet of stack gas (lb/dscf) to mass per unit of fuel input (lb/MMBtu). The following conversion factors were used.

Conversion Factors for Concentration:

From	To	Multiply By
gr	lbs	0.0001
ppm NOx	lb/scf	$1.194 * 10^{-7}$
ppm SO_2	lb/scf	$1.660 * 10^{-7}$
ppm CO	lb/scf	$0.726 * 10^{-7}$
ppm VOC	lb/scf	$1.142 * 10^{-7}$

The data in lb/dscf, at measured stack oxygen percent, were converted to lb/dscf at zero percent oxygen and then multiplied by Fuel-Factors (F-Factor). F-Factors are expressed in units of dry standard cubic feet of stack gas at zero percent oxygen per million British thermal units of fuel heat input (dscf/MMBtu @ 0% O_2). Equation 1 was used for these calculations.

Equation 1: Oxygen-based F factor, dry basis

$$E = C_d F_d 20.9/(20.9-\%O_{2d})$$

where:

Cd = pollutant concentration

Fd = 9,240 dscf/10^6 Btu

$\%O_{2d}$ = percent stack oxygen

The product of Equation 1 is an emission factor in units of pound of pollutant per million British thermal units (lb/MMBtu).

An emission factor was calculated for each individual test run. Next, an average factor was calculated for each test from the individual run factors. Site-specific F-Factors were used in these calculations, when provided. When they were not provided, F-Factors provided in Method 19 of Appendix A, Part 60, of the Code of Federal Regulations were used. The Method 19 F-Factor for Wood (9,240 dscf/MMBtu) was used for those tests where the fuel was described as bark and wet wood, wet wood, or dry wood. The data was grouped by test id, with some exceptions.

Reported emissions values that were based on method detection limits were handled according to the procedures outlined in *Procedures For Preparing Emission Factor Documents*, U.S. EPA, EPA-454/R-95-015, November, 1997. Non-detect values were not used in averaging when they were greater than detected values. Non-detect values less than detected values were divided by one half and included in developing the average factor. However, if there were three runs of non-detects and the average non-detect value was the maximum point in the data set, the non-detects were not used. When all runs and tests are non-detects, half the detection limit is presented with a "less than" sign before the emission factor (e.g., <2.3E-05 lb/MMBtu).

The process data used to characterize the emission sources and the emissions data used to develop the factors are summarized in the electronic spreadsheets available for this section. They are available on the web at http://www.epa.gov/ttn/chief.

3.3 Emission Factor Ratings

The emission factors were rated according to the criteria in EPA's procedure document, entitled *Procedures for Preparing Emission Factor Documents.* This document can be found on EPA's CHIEF website (www.epa.gov/ttn/chief).

4.0 REVISED EMISSION FACTORS

This section documents the revisions made to Section 1.6 of the 5th edition of AP-42.

4.1 General Text Changes

The EPA received minor comments on the text. As a result, editorial revisions were made to the text to improve clarity.

4.2 Filterable Particulate Matter (PM)

Several emission factors for filterable PM were replaced with new factors. The old (2/99) AP-42 emission factors did not have information on fuel moisture content and sources were only separated by wood type and boiler type. The new factors are grouped by wood type, fuel moisture content and PM control device. Analysis of the new data indicated that fuel type and moisture content, does make a difference in emissions for uncontrolled and mechanical collector equipped boilers, therefore separate factors were developed for each of these emission source categories. However the analysis also showed that fuel type and moisture content did not make a distinguishable difference when higher performing control devices such as wet scrubbers, fabric filters, ESPs, or electrolyzed gravel bed filters were used for PM control. The burning of pure wood versus mixed wood species was also examined. The data indicated that neither pure versus mixed wood species, nor eastern vs western wood species, have any significant impact on the emissions, therefore these data were not separated.

Table 1 shows the summary statistics for the PM factors. The old (2/99) AP-42 factors have been converted to lb/MMBtu for this table. The units for the minimum (Min) and maximum (Max) are also lb/MMBtu. Std means the standard deviation of the data set in lb/MMBtu.

Table 1. Filterable PM Emission Factors

Fuel	PM Control Device	Old (2/99) AP-42 Factor (lb/MMBtu)	New (7/01) PM Factor (lb/MMBtu)	Count	Min	Max	Std
Bark	No Control	5.2	0.56	4	0.299	0.928	0.270
Bark/ Wet Wood	No Control	0.8	0.56	4	0.299	0.928	0.270
Dry Wood	No Control	None	0.40	15	0.181	0.844	0.183
Wet Wood	No Control	0.97	0.33	17	0.118	0.624	0.179
Bark	Mechanical Collector	1.6	0.54	1	0.541	0.541	NA
Bark/Wet Wood	Mechanical Collector	0.6	0.35	6	0.169	0.892	0.278
Dry Wood	Mechanical Collector	None	0.30	30	0.125	0.625	0.128
Wet Wood	Mechanical Collector	0.46	0.22	42	0.0001	1.89	0.332
All Fuels	Electrolyzed Gravel Bed	None	0.10	2	0.048	0.160	0.079
All Fuels	Wet Scrubber	None	0.066	32	0.031	0.131	0.021
All Fuels	Fabric Filter	None	0.1	8	0.001	0.527	0.179
All Fuels	ESP	None	0.054	10	0.002	0.469	0.146

4.3 Condensible PM

The condensible PM emission factor was developed as a result of the new data. Data for the condensible PM factor were from sources that were uncontrolled for PM as well as sources with PM control devices, such as electrolyzed gravel bed filter, electrostatic precipitator, fabric

filter, or wet scrubber. This is appropriate because PM control devices do not appear to affect condensible PM. Factors for all fuel types, all firing configurations, and all control device types were averaged together to develop a single factor. Analysis also found that different fuel types do not appear to affect condensible PM. Table 2 shows the summary statistics of the data. The units for the minimum (Min) and maximum (Max) are also lb/MMBtu. Std means the standard deviation of the data set.

Table 2. Condensible Particulate Matter Emission Factor

Fuel	PM Control Device	Old (2/99) AP-42 Factor (lb/MMBtu)	New (7/01) PM Factor (lb/MMBtu)	Count	Min	Max	Std
All Fuels	All Controls/ No Controls	None	0.017	89	5.18 E-05	0.224	0.028

4.4 Filterable Particulate Matter Less than 10 Microns (PM10) And Filterable Particulate Matter Less Than 2.5 microns (PM2.5)

There were very little test data available for filterable PM10 and no data were available for filterable PM2.5. Therefore, it was decided to use the emission factors for filterable PM and the particle size distribution information for wood/bark-fired boilers provided in Table 1.6-5 in the July 2001 version of Section 1.6 of AP-42 to develop the emission factors for filterable PM10 and filterable PM2.5. The “Bark-fired Spreader Stoker Boiler” particle size distribution table was not used in the new section because EPA believed the data was atypical. The overall PM emissions were about 10 times typical PM emissions from wood residue boilers, so the data was suspect as far as appling the size distribution to other boilers/fuel combinations. This was Table 1.6-6 in the last published section and was used to generate some of the factors in the 1999 draft.. Some of the PM10 and PM2.5 factors from the 1999 draft increased when it was decided to use the wood/bark-fired size distribution table to generate the factors.

4.5 Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Sulfur Dioxide (SO_2)

All emission factors for NO_x, CO, and SO_2 were replaced with new factors. The old (2/99) AP-42 NO_x emission factors separated the data by boiler configuration. The average NO_x emission factors for each individual combustor were grouped by fuel type. All of the data were from boilers that had no NO_x emission controls and were from boilers burning either dry wood or bark and bark/wet wood. After analysis of the data, the AP-42 factors were determined by grouping the data by dry or wet wood regardless of firing configuration. Table 3 shows the summary statistics of the data. The old (2/99) AP-42 factors have been converted to lb/MMBtu for this table. When there are multiple numbers in a "Old AP-42 Factor" column, it means that it is not clear which of the older AP-42 factors apply here, since they had been organized by fuel cell/dutch oven, stoker, and FBC. The units for the minimum (Min) and maximum (Max) are also lb/MMBtu. Std means the standard deviation of the data set.

Table 3. NOx Emission Factors

Fuel	Firing Configuration	Old (2/99) AP-42 Factor (lb/MMBtu)	New NOx Factor (lb/MMBtu)	Count	Min	Max	Std
Bark/ Wet Wood	All	0.042/0.16/0.22	0.22	82	0.023	1.281	0.18
Dry Wood	All	0.042/0.16/0.22	0.49	8	0.187	0.863	0.25

The CO emission factors for each individual combustor were no longer grouped by firing configuration which was done in the old (2/99) AP-42 version. Upon final analysis of the data, the AP-42 factors were developed by grouping the all the data together except for Fluidized Bed Combustors. A separate factor was developed for FBC's by averaging the 9 data points in the data set. One factor was developed for all other CO data supported by 128 data points. The CO

data was combined because there was not a significant difference in emission factors when separated by fuel type or control device.

Table 4 shows the summary statistics of the data. The old (2/99) AP-42 factors have been converted to lb/MMBtu for this table and were originally presented for fuel cell/dutch oven and stoker boilers separately. When there are multiple numbers in a "Old AP-42 Factor" column, it means that it is not clear which of the older AP-42 factors apply here, since they had been organized by fuel cell/dutch oven and stoker. The units for the minimum (Min) and maximum (Max) are also lb/MMBtu. Std means the standard deviation of the data set.

Table 4. CO Emission Factors

Fuel	Firing Configuration	Old (2/99) AP-42 Factor (lb/MMBtu)	New CO Factor (lb/MMBtu)	Count	Min	Max	Std
All Fuels	All except FBC	0.73/1.5	0.60	128	0.028	2.578	0.51
All Fuels	FBC	0.16	0.17	9	0.016	0.943	0.30

The SO_2 emission factors for each individual combustor were averaged to develop a single AP-42 emission factor. The SO_2 emissions are affected mainly by the sulfur content of the fuel and are not affected by fuel moisture content, the type of firing configuration, or PM control device type. The new data include tests from Bark and Wet Wood, Dry Wood, and Wet Wood. No data from bark combustion were available. Thus, the new factor of 0.025 lb/MMBtu (supported by 28 data points) represents SO_2 emissions from all fuels and all firing configurations. Table 5 shows the summary statistics for the SO_2 data. The old (2/99) AP-42 factors have been converted to lb/MMBtu for this table. The units for the minimum (Min) and maximum (max) are also lb/MMBtu. Std means the standard deviation of the data set.

Table 5. SO_2 Emission Factor

Fuel	Firing Configuration	Old (2/99) AP-42 Factor (lb/MMBtu)	New SO2 Factor (lb/MMBtu)	Count	Min	Max	Std
All Fuels	All	0.0083	0.025	28	0.0004	0.126	0.037

4.6 Speciated Organic Compounds, Total Organic Compounds (TOC), Volatile Organic Compounds (VOC), and Carbon Dioxide (CO_2)

All emission factors for speciated organic compounds, TOC, VOC, and CO_2 were replaced with new factors. The old (2/99) AP-42 factors separated the data by boiler type. Most of the organic pollutants are emitted at very low levels and their emissions do not appear to be dependent on fuel type, firing configuration and PM controls. Thus, a single factor was developed for each pollutant and is intended to represent all fuel types (wet or dry), firing configurations, and PM controls (including no controls). No data were identified from a wood combustor equipped with organic emissions controls.

The TOC emission factor was developed by summing the emission factors for each organic compound. For comparison, a TOC emission factor was also calculated using emissions data reported as "Total Hydrocarbons." This estimated factor (0.038 lb/MMBtu) was lower in value than the TOC factor calculated by summing the individual compound factors (0.058 lb/MMBtu). Because the reference test method for total hydrocarbons does not measure all organic compounds, a TOC factor based on speciated organic compounds is much more accurate when sufficient speciated data are available.

The VOC emission factor was developed by summing the emission factors for each organic compound except acetone, chlorine, dichloromethane (methylene chloride), hydrogen chloride, methane, tetrachloroethene, formaldehyde, and 1,1,1-trichloroethane.

No new data for nitrous oxide were identified and the two old factors in Section 1.6 are retained are the only data available. The two factors were averaged together to develop a single AP-42 factor.

For CO_2, average combustor factors for all fuel types, firing configurations, and PM controls (including no controls) were grouped together and a single average taken. CO_2 emissions are not affected by fuel moisture content, firing configuration, or PM controls. The new AP-42 factor represents all fuel type, firing configuration, PM controls, and no controls.

Table 6 shows the summary statistics of the TOC, VOC, and CO_2 data. The speciated organic compounds are presented in a separate Excel© spreadsheet. The old (2/99) AP-42 factors have been converted to lb/MMBtu for this table and were originally presented for fuel cell/dutch oven and stoker boilers separately. When there are multiple numbers in a "Old AP-42 Factor" column, it means that it is not clear which of the older AP-42 factors apply here, since they had been organized by fuel cell/dutch oven and stoker. The units for the minimum (Min) and maximum (Max) are also lb/MMBtu. Std means the standard deviation of the data set. For TOC and VOC, "count" means how many compounds were summed to obtain the factor.

Table 6. TOC, VOC and CO_2 Emission Factor

Pollutant	Fuel	Firing Configuration	Old (2/99) AP-42 Factor (lb/MMBtu)	New (7/01) Factor (lb/MMBtu)	Count	Min	Max	Std
TOC	All	All	0.019/0.024	0.06	86	8.58E-12	2.07E-02	3.10E-03
VOC	All	All	None	0.04	79	8.58E-12	2.07E-02	2.41E-03
CO_2	All	All	231	195.2	96	0.017	323	30.7

4.7 Trace Elements

All emission factors for trace elements were replaced with new factors, however the old (2/99) AP-42 category with all fuels and all boiler configurations grouped together remained the same. The trace element missions are affected mainly by their content in the fuel and not by fuel moisture content or firing configuration. Most of the data were from PM controlled sources with only a few tests at uncontrolled sources. The factors developed from the uncontrolled tests were very similar in value to those developed from controlled tests and it was decided to average all data (PM controlled and uncontrolled) together to develop a single AP-42 emission factor.

Table 7 shows the summary statistics of the data. The old (2/99) AP-42 factors have been converted to lb/MMBtu for this table. The units for the minimum (Min) and maximum (Max) are also lb/MMBtu. Std means the standard deviation of the data set.

Table 7. Trace Elements

Organic Compound	Old (2/99) AP-42 Factor (lb/MMBtu)	New (7/01) Factor (lb/MMBtu)	Count	Min	Max	Std
Antimony	None	7.94E-06	3	4.23E-07	2.29E-05	1.30E-05
Arsenic	9.68E-06	2.20E-05	23	2.49E-11	2.88E-04	6.12E-05
Barium	4.84E-04	1.74E-04	5	2.02E-05	3.47E-04	1.32E-04
Beryllium	None	1.09E-06	13	8.65E-13	5.68E-06	1.68E-06
Cadmium	1.87E-06	4.09E-06	24	3.01E-13	1.63E-05	4.83E-06
Chromium	1.43E-05	2.06E-05	27	3.99E-12	1.61E-04	3.40E-05
Chromium, hexavalent	5.06E-06	3.51E-06	8	5.90E-08	7.33E-06	2.85E-06
Cobalt	1.43E-05	6.50E-06	7	1.25E-07	2.69E-05	1.00E-05
Copper	2.09E-05	4.85E-05	24	2.78E-11	1.77E-04	5.80E-05
Iron	4.84E-03	9.93E-04	1	9.93E-04	9.93E-04	
Lead	None	4.77E-05	26	1.60E-11	2.84E-04	7.61E-05
Manganese	9.79E-04	1.55E-03	24	9.66E-11	9.77E-03	2.41E-03
Mercury	7.15E-07	3.54E-06	19	8.85E-13	4.20E-05	9.52E-06
Molybdenum	2.09E-05	2.07E-06	2	1.13E-06	3.01E-06	1.33E-06
Nickel	6.16E-05	3.33E-05	22	2.97E-12	2.62E-04	6.17E-05
Phosphorus	None	2.74E-05	2	1.93E-05	3.54E-05	1.14E-05
Potassium	8.58E-02	3.88E-02	1	3.88E-02	3.88E-02	
Selenium	1.98E-06	2.79E-06	15	2.31E-12	1.10E-05	2.80E-06
Silver	None	1.74E-03	1	1.74E-03	1.74E-03	
Sodium	1.98E-03	3.63E-04	1	3.63E-04	3.63E-04	
Strontium	None	1.01E-05	1	1.01E-05	1.01E-05	
Tin	3.41E-06	2.29E-05	2	6.63E-06	3.91E-05	2.30E-05
Titanium	None	2.01E-05	1	2.01E-05	2.01E-05	
Vanadium	1.32E-05	9.77E-07	2	5.94E-07	1.36E-06	5.42E-07
Yttrium	None	3.01E-07	1	3.01E-07	3.01E-07	
Zinc	4.84E-04	4.20E-04	25	3.11E-10	2.78E-03	6.24E-04

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21. *Stack Emission Test Report on Hogged Wood Fired Boiler # 5 at Snow Mountain Pine of Oregon, LTD, Burns, Oregon*. Horizon Engineering. December 1, 1992.

22. *Source Emission Evaluation on Hogged Fuel Boiler # 2 at International Paper Company, Gardiner, Oregon*. AMTEST Air Quality, Inc. November 12, 1993.

23. *Source Emission Evaluation on Boiler # 1 Outlet and Boiler # 2 Outlet at Bohemia Inc., Gardiner, Oregon*. AMTEST Air Quality, INC. May 15-16 1990.

24. *Stationary Source Sampling Report for Lexington Furniture Industries Plant Number 10, Hildebran, North Carolina. ABCO Boiler Stack*. Trigon Engineering Consultants, Inc. December, 1993.

25. *Stationary Source Sampling Report. Lexington Furniture Industries Plant Number 11, Mocksville, North Carolina*. Entropy Environmentalists. August 15 and 16, 1991.

26. *Stationary Source Sampling Report for Lexington Furniture Industries, Spruce Pine, North Carolina*. Trigon Engineering Consultants, Inc. December, 1995.

27. *Stationary Source Sampling Report. ERG Reference No. 0539. Emissions Testing For: Carbon Monoxide; Dioxins; Furans; Nitrogen Oxides; Particulate (PM-10); Sulfur Dioxide; Total Hydrocarbons*. Environmental Technical Group, Inc. May 19, 1998.

28. *Source Emission Testing of the Wood-Fired Boiler "C" Exhaust at Bohemia, Inc. Rocklin, California*. Performed for the Timber Association of California. Galston Technical Services. December, 1990.

29. *Results of the July 7, 1993 Air Emission Compliance Testing on the Wood-fired Boiler at the Ashley Furniture Facility, Arcadia, Wisconsin*. Interpoll Laboratories, Inc. August 16, 1993.

30. *Results of the April 14, 1994 Air Emission Compliance Testing on the Wood-fired Boiler at the Ashley Furniture Facility, Arcadia, Wisconsin*. Interpoll Laboratories, Inc. May 11, 1994.

31. *Results of the October 27, 1994 Air Emission Compliance Testing of the Boiler at the Endeavor Hardwoods Facility, Lyndon Station, Wisconsin*. Interpoll Laboratories, Inc. November 16, 1994.

32. *Source Test Report. Source Emission Testing of the Wood-fired Boiler at Ethan Allen, Inc - Mayville Division. Mayville, New York.* Galson Corporation. May 13, 1994.

33. *Results of the October 27, 1994 Air Emission Compliance Test of the Boiler at the Endevor Hardwoods Facility, Lyndon Station, Wisconsin*. Interpoll Laboratories. October 27, 1994.

34. *Results of the November 10, 1994 Air Emission Compliance Testing on the Wood-Fired Boiler at the Ashley Furniture Facility, Arcadia, Wisconsin*. Interpoll Laboratories, Inc. December 2, 1994.

35. *Report to Laminated Products, Inc. Kenosha, Wisconsin for Particulate Emissions Testing Wood-Fired Boiler, May 31, 1994.* Environmental Technology & Engineering Corp. July 7, 1994.

36. *Report to Laminated Products, Inc. Kenosha, Wisconsin for Particulate Emissions Testing Wood-Fired Boiler, September 2, 1994.* Environmental Technology & Engineering Corp. September 19, 1994.

37. *Source Emission Evaluation on Wellons Boiler Exhaust Stack at WTD Industries-Trask River Lumber Company, Tillamook, Oregon*. AMTEST Air Quality, INC. August 30, 1995.

38. *Wood Fired Boiler Emission Test at Marion Plywood Corp., Marion, Wisconsin*. Badger Laboratories & Engineering. September 2 & 3, 1992.

39. *Wood Fired Boiler Emission Test at Marion Plywood Corp., Marion, Wisconsin*. Badger Laboratories & Engineering. August 11, 1992.

40. *Results of the January 18, 1990 Particulate Emission Compliance Test on the Konus Common Stack at the Louisiana Pacific Corporation Facility, Hayward, Wisconsin*. Pace Laboratories, Inc. January 18, 1990.

41. *Source Emission Testing of the Wood-Fired Boiler #3 Exhaust at Georgia Pacific, Fort Bragg, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

42. *Source Emission Testing of the Wood-Fired Boiler #5 Exhaust at Roseburg Forest Products, Anderson, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

43. *Emission Test Report on the Hogged Fuel Fired Boiler at Tillamook Lumber Company, Tillamook, Oregon*. Horizon Engineering. December 20, 1994.

44. *Emission Test Report on Wood Waste Boiler at Timber Products, Medford, Oregon*. BWR Associates, Inc. July 22, 1993.

45. *Emission Test Report on Wood Waste Boiler at Timber Products, Medford, Oregon*. BWR Associates, Inc. November 18, 1993.

46. *Emission Test Report on Wood Waste Boiler at Timber Products, Medford, Oregon*. BWR Associates, Inc. March 26, 1991.

47. *Source Emission Testing of the Wood-fired Boiler At Catalyst Hudson, Inc., Anderson, California*. Galson Technical Services, Inc. February, 1991.

48. *Results of the May 18, 1988 Particulate and Carbon Monoxide Emission Compliance Test on the No.1 Boiler at the Norenco Cogeneration Facility, Ladysmith, Wisconsin.* Interpoll Laboratories. May 19, 1988.

49. *Emission Test Report on Wood Waste Boilers at Stone Forest Industries, White City, Oregon*. BWR Associates, Inc. December 21, 1992.

51. *Results of the February 1, 1994 Air Emission Compliance Test on the GEKA Common Stack at the Louisiana Pacific Waferboard Plant, Tomahawk, Wisconsin*. Interpoll Laboratories, Inc. February 1, 1994.

52. *Report to Laminated Products, Inc. Kenosha, Wisconsin for Particulate Emissions Testing Wood-Fired Boiler, July 7, 1995*. Environmental Technology & Engineering Corp. July 17, 1995.

53. *Results of the August 17-19, 1993 Air Emission Compliance Test at the Louisiana Pacific Waferboard Plant, Tomahawk, Wisconsin*. Interpoll Laboratories, Inc. August 17-19, 1993.

54. *Source Emission Testing of the Wood-Fired Boiler Exhaust at Sierra Pacific, Burney, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

55. *Source Emission Testing of the Wood-Fired Boiler #1 Exhaust Stack at Wheelabrator Shasta Energy Company (TAC Site 9), Anderson, California*. Performed for the Timber Association of California. Galston Technical Services. January, 1991.

56. *Source Emission Testing of the Wood-Fired Boiler "C" Exhaust at Pacific Timber, Soctia, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

57. *Source Emission Testing of the Wood-Fired Boiler at Yanke Energy, North Fork, California*. Performed for the Timber Association of California. Galston Technical Services. January, 1991.

58. *Source Emission Testing of the Wood-Fired Boiler Exhaust at Miller Redwood Company, Crescent City, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

59. *Nitrogen Oxide Emissions from a Pilot Plant Spreader Stoker Bark Fired Boiler*. R.A. Kester, Department of Civil Engineering. University of Washington, Seattle, WA. December, 1979.

60. *Stack Emission Test Report on Hogged Wood Fired Boiler Plant at Champion International Corporation, Roseburg, Oregon*. Horizon Engineering. August 19, 1991.

61. American Furniture Manufacturers Association Test Report. *Determination of Nitrogen Oxide and Carbon Monoxide Emissions. September 22, 23, and 24, 1998*. Air Monitoring Specialists. September, 1998.

62. *Results of the April 20 & 21, 1993 Air Emission Tests on the Cleaver Brooks and Kidwell Wood-Fired Boilers at the Eggers Industries Plant in Two Rivers, Wisconsin.* Interpoll Laboratories, Inc. May 25, 1993.

63. *Report to Eggers Industries, Inc., Two Rivers, Wisconsin for Stack Emission Test, West Plant Wood-Fired Boiler*. Environmental Technology And Engineering Corporation. August 5, 1997.

64. *Emission Test Program on the Wood-Fired Boiler at Goodman Forest Industries, Ltd. Goodman, Wisconsin*. Air Environmental. Inc. December 14, 1995.

65. Emission Factor Documentation for AP-42 Section 1.6- Wood Waste Combustion in Boilers. Technical Support Division, Office of Air Quality Planning and Standards. U.S. Environmental Protection agency. Research Triangle Part, NC. April, 1993.

66. *Report to Eggers Industries, Inc., Two Rivers, Wisconsin for Stack Emission Test, West Plant Wood-Fired Boiler*. Environmental Technology And Engineering Corporation. February 27, 1996.

67. *Lamico, Inc., Emission test at 474 Mariod Road, Oshkosh, WI, October 5 & 6, 1989*. Badger Laboratories & Engineering Co., Inc. November 1, 1989.

68. *Cleaver-Brooks Boiler Stack Particulate Emission Testing on November 8, 1994*. Environmental Services of America, Inc. December 7, 1994.

69. *Inhabable Particulate Source Category Report for External Combustion Sources*, EPA Contract No. 68-02-3156, Acurex Corporation, Mountain View, CA, January 1985.

70. Oregon Department of Environmental Quality Database, Process Data. State of Oregon, 2001.

71. Wood Products in the Waste Stream-Characterization and Combustion Emissions, U.S. Environmental Protection Agency, Control Technology Center, October, 1996.

72. Test Report prepared for American Furniture Manufacturing Association. Air Monitoring Specialists, Inc. December, 1996.

6.0 REVISED SECTION 1.6

The revised draft section will be included here after external reviewer comments have been incorporated and the section is finalized.

APPENDIX A

Public Comments on Section 1.6 Wood Residue Combustion

1.0 INTRODUCTION

In September, 1999, the Environmental Protection Agency submitted for public review the revisions to the 5th edition AP-42 Section 1.6 Wood Residue Combustion in Boilers. The EPA received a total of 6 letters commenting on the proposed revisions submitted mainly by owners and operators of boilers and two industry trade associations.

This document summarizes the AP-42 changes recommended by the commenters and discusses how each of these recommendations was addressed in the May 2001 revision of AP-42 Section 1.6.

2.0 PUBLIC COMMENTS AND ORGANIZATION OF THIS DOCUMENT

The commenters and their affiliations are listed in Table 1. Section 3.0 presents a summary of the comments on the revised section.

TABLE 1. LIST OF COMMENTERS AND THEIR AFFILIATIONS

Commenter ID Number	**Commenter and Affiliation**
AP-1	J. Pinkerton National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI) Research Triangle Park, NC
AP-2	A. Counts American Furniture Manufacturers Association (AFMA) High Point, NC
AP-3	J. Stevens State of Missouri Department of Natural Resources
AP-4	C. Rollins H.M. Rollins Company, Inc. Gulfport, MS
AP-5	Duane Mummert Westvaco Company
AP-6	Oregon Department of Environmental Quality

3.0 COMMENTS ON REVISED SECTION 1.6

The comments summarized below are organized in the same order as the relevant parts of the revised AP-42 section.

3.1 OVERALL COMMENTS

Comment: Two commenters (AP-1, AP-2) asked EPA to not refer to bark, sawdust, trim, wood fines, sanderdust, chips, and hogged fuel as "wastes". The commenter added that wastes are not burned in boilers. They suggested using wood fuels or wood residues as a substitute. Waste creates an incorrect perception of AP-42 users that combustion devices burning these materials should be treated as incinerators rather than boilers. Wood materials are only considered waste when burned in an incinerator without energy recovery to reduce volume requiring disposal.

Response: EPA will use the phrase "wood residue".

Comment: One commenter (AP-6) submitted a database of test results from the State of Oregon. The commenter stated the old AP-42 section could be slanted to eastern species of wood. The commenter believes there are significant differences in western and eastern wood heating values.

Response: EPA analyzed the Oregon data and compared these to the existing data. EPA determined that eastern and western species of wood did not display significant differences in heating values or emissions. As a result, the Oregon data was combined with the old database and new emission factors were developed.

Comment: One commenter (AP-3) asked EPA what type of quality assurance was performed on the data to insure the tests are representative to all conditions.

Response: All data used by EPA was collected using EPA approved methods presented in "Procedures for Preparing Emission Factor Documents." These procedures include a review for representativeness of the emission source and describe how this review is conducted.

3.2 Comments on 1.6.1 GENERAL

Comment: One commenter (AP-1) indicated that the estimated total capacity of the 1600 wood-fired boilers in the U.S. is too large. The commenter thought that 1600 boilers with a total capacity of over 5×10^{11} Btu/hr implied that an average size boiler would be 312×10^{6} Btu/hr. The commenter thought that is too large for an average wood fired boiler.

Response: The EPA decided not to make any changes as a result of this comment. This general data on boiler characteristics is for general user information, and has no affect on the emission factors presented in AP-42.

3.3 Comments on 1.6.3 EMISSIONS AND CONTROLS

Comment: One commenter (AP-1) asked EPA to clarify that the paragraph describing the factors affecting particulate matter emissions do not apply to CO, VOC and NO_x emissions. The commenter thought that the draft text indicated the list of factors affecting emissions affect CO, VOC and NOx.

Response: The EPA agrees that the paragraph is not clear and will make revisions to the text.

3.4 Comments on 1.6.4 CONTROLS

Comment: One commenter (AP-1) asked EPA to replace the term "fuel-fired" with "wood-fired" in the first paragraph of that section. The same commenter asked EPA to delete the reference to fabric filters in the second paragraph and discuss them in the fourth paragraph. The commenter added that fabric filters are rarely considered when high collection efficiencies are necessary. The commenter also stated that in the fifth paragraph EPA should mention that with respect to SNCR applications on wood-fired boilers, high ammonia injection rates can lead to significant ammonia slip and fine ammonium particulate formation.

Response: The EPA will make the suggested revisions, except for the SNCR suggested text changes.

Comment: One commenter (AP-3) asked what the assumed control efficiency was for the multiple cyclones. The commenter suggested that EPA encourage facilities to calculate their own controlled emission factors since some combustion devices have lower and higher control efficiencies.

Response: The EPA will clarify the ranges of control efficiency values for all of the control devices.

3.5 Comments on TABLE 1.6-2

Comment: One commenter (AP-1) stated that there is no entry in the table for sanderdust-fired units although the text mentions sanderdust-fired boilers at particleboard plants may have high NO_x emissions as compared to bark-fired boilers. The commenter suggests the following language to modify that section:

"NO_x emissions from wood combustion are largely dependent on fuel nitrogen content. Board trim and sanderdust from wood panel plants that use urea-formaldehyde resins can be as high as 3% due to the urea nitrogen. This higher nitrogen content would be expected to lead to higher NOx emissions from boilers burning these materials."

Response: The EPA will make revisions to Section 1.6.3.1 Criteria Pollutants to explain the factors affecting NOx emissions.

Comment: One commenter (AP-2) stated that combustion unit B38 (Eggers Industries in Two Rivers, Wisconsin, tests reference numbers 30 and 81) should be deleted. The unit is small compared to the other units and the commenter questions whether it is even an industrial boiler. The commenter requests that EPA consider the Eggers data to be non-representative and not be considered in the NOx emission factor.

Response: The EPA examined the test report for combustion unit B38 and determined the boiler was in the range of wood fired boilers.

Comment: The same commenter (AP-2) stated that B19 (Bohemia Inc. in Rocklin, California, test reference number 46) should be considered an outlier and not included in the CO emission factor calculation. The test result was 3.2 times higher than the next highest test result and the commenter feels the result is questionable.

Response: The EPA performed an outlier test to see if the point lie outside of the mean plus 4 standard deviations. This data point was within mean plus 4 standard deviations. Also new data from the State of Oregon has multiple data points in the same order of magnitude of B19.

Comment: The commenter (AP-1) stated that reference 11 was not one of the four reference in the footnote for the SO2 emission factor. If the reference was not used it should be deleted from the reference list. However that reference has been used in AP-42 in the past and should be included in this update. The background report does not mention if the data from reference 11 were used or not.

Response: The reference contained information on the sulfur content of bark and how that contributes to SO2 emissions. The information was used in the Emissions and Controls section of the chapter.

Comment: One commenter (AP-4) stated that the draft AP-42 factors for CO are lower than the old factors. The commenter stated that most stoker boilers at wood products plants in the South probably cannot operate at the rated capacity and emit less CO than the old AP-42 number. The commenter does not think EPA included the data from NCASI "Carbon Monoxide Emissions from Selected Sources Based on Short-Term Monitoring Records", January 1984. This data contained data significantly higher than the proposed factors.

Response: The EPA included all data available during the time of the analysis and believe the emission factor is representative of CO emissions from wood residue fired boilers. The specific report mentioned by the commenter was not among the available data and is a relatively old reference.

3.6 Comments on TABLE 1.6-3

Comment: One commenter (AP-1) stated that just assigning the A through E rating value for the emission factors does not provide enough essential information. The commenter thinks that AP-42 users would like to see; how many sources (or source tests) were used to develop the number for each compound, including how many source tests had non-detects that were included

at one-half the detection limit. Also believes that the highest and lowest values in the data set for each compound should be identified and identify the number of values below method detection limits.

Response: This type of information is included in the background document which is a supplement to Section 1.6.

Comment: The same commenter (AP-1) questioned the reasonableness of combining all available data into one set of emission factors. Averaging test results without considering varying combustion conditions does not seem reasonable especially when normal conditions are averaged with unstable or inefficient combustion conditions. Additionally one or two abnormally high emission test results can significantly affect the average value, especially when the number of test results is small. Median values or geometric means, rather than arithmetic averages of the emission factors should be used where there are extremely high values above the mean and factors of 1000 higher than the next highest value. This would minimize the impact of these highly questionable data.

Response: The large variability between tests is not unusual. The emission factors are suppose to represent national averages, which include a range of different boilers that are operated at a broad range of conditions. The EPA's standard operating procedure is to use the arithmetic average. It would be inconsistent with the other AP-42 sections to use the median or geometric mean.

Comment: The same commenter (AP-1) requested that EPA re-evaluate some of the test reports and exclude results of those units that burn materials other than wood. Some emission tests were conducted when other materials like demolition debris, manufacturing scrap which were fired in the boiler. These materials could contain painted, stained, treated, laminated or otherwise altered wood products which could affect emission of some compounds.

Response: The EPA re-analyzed the test reports and found that three test reports should be deleted because the wood residue contained agricultural, urban and flakeboard waste which is not consistant with the typical wood residue used for these boilers.

Comment: The same commenter (AP-1) stated the TOC factor has several shortcomings. Footnote "ai" indicates that all factors except N2O and CO2 are included in the TOC total, HCL should not be included.

Response: The commenter is correct and emission factor and footnote were be revised to exclude HCL from the TOC emission factor.

Comment: The same commenter (AP-1) stated that summing of the individual factors gives undue weight to a few compounds with relatively little data, for example valderaldehyde represents one-third of the TOC factor but only comes from the average of two tests.

Response: The EPA did not receive an alternative way to calculate the emission factor from the commenter. The EPA believes they have used the most appropriate way to present the TOC factor based on the available data.

Comment: The same commenter (AP-1) stated that the new TOC factor is the actual weight of all the individual compounds however the earlier TOC (and VOC) factors were reported either as carbon, methane or propane equivalents and were based on EPA Method 25 or 25A sampling procedures. The commenter suggests EPA replace the TOC and VOC emission factors with a factor based on Method 25 and 25A results.

Response: The method used by EPA to develop the factor is the only method applicable to the data available. However this method added relatively little error to the other uncertainties already present in the data. Please refer to the background document for more details on the method for developing the TOC emission factor.

Comment: The commenter (AP-1) indicated that footnote "aj" is used twice.

Response: The EPA will make this correction.

Comment: One commenter (AP-4) indicated that the new factors for the chlorinated dioxins and furans in some cases are two or three orders of magnitude higher than the previously published factors. The commenter stated that highly chlorinated dioxins are the most prevalent species, so more OCDD would be expected compared to HxDD. The commenter questioned the data from test B138 which provided the higher HxDD data. The commenter asked if the test was valid or if the data was entered into the database correctly. The commenter also provided a quick calculation example of the labor required to fill out SARA reports if these draft factors go final for annual reporting of 5,519 lbs of dioxins.

Response: The EPA reviewed the test report in question and found that run 1 of the test experienced an unexplained problem. The EPA decided to delete the first run and recalculate the emission factor with the remaining data.

3.7 Comments on TABLE 1.6-4

Comment: The commenter (AP-1) questioned the reasonableness of combining all available data into one set of emission factors.

Response: The commenter did not suggest an alternative method to develop the emission factors. This is the standard EPA method when developing national emission factors.

Comment: The same commenter (AP-1) questioned the results for boiler B45 for several metals which were orders of magnitude lower than for other units tested, suggesting some type of calculation error was made in the B45 test report.

Response: The EPA reviewed the test report for combustion unit B45 and did not find any calculation errors. In addition, all the metal emission factors have been revised based on additional data received from the State of Oregon and an EPA report from the Control Technology Center.

Comment: The two commenters (AP-1, AP-5) stated that the hexavalent chromium emissions were several orders of magnitude higher than total chromium emissions for this unit.

Response: The EPA revised the emission factors based on new data received from the State of Oregon and an EPA report from the Control Technology Center. The hexavalent chromium is now lower than the total chromium emission factor.

3.8 Comments on TABLES 1.6-5, 1.6-6, FIGURES 1.6-1, 1.6-2

Comment: The commenter (AP-1) requests that EPA delete the mass emission factors from the tables. The mass emission scales on the figures should be replaced with percentage scales. The same commenter stated EPA should define the acronym "DEGF" in Table 1.6-6. Another commenter (AP-3) stated that Tables 1.6-5 and 1.6-6 are difficult to understand. The commenter suggested that an example or a small paragraph explaining how to use the tables to come up with emission factors for different particle sizes would be helpful.

Response: The EPA has decided to delete table 1.6-5 and figure 1.6-1. The revised PM-10 and PM-2.5 emission factors will be calculated using Wood/Bark-fired Boilers table.

3.9 Comments on specific emission factors

Comment: One commenter (AP-1) provided comments on many of the gaseous compounds emission factors.

The EPA reviewed the comments and grouped the responses as follows

Response: The commenter (AP-1) felt that many data sets contained test reports or specific data points that were not representative of the data set and therefore thought the data points should not be included in calculating the emission factor. The EPA examined all of the gaseous compound emission factors and in many cases reviewed the corresponding test report. For the following list of compounds, EPA deleted some (and occasionally all) of the data points and recalculated the emission factor. The decision to delete a test report or data point was based on information EPA found in the test reports. The deleted compounds were either from a report that EPA felt contained fuel that was atypical of the residue used at most "wood residue" fired boiler plants or the report contained data points that were above four standard deviations plus the mean of the average emission factor for the data set.

Acetaldehyde
Acetone
Anthracene
Benzo(a)pyrene
Carbon Tetrachloride
Chlorine
Chrysene
Crotonaldehyde
Chlorobenzene
2-Butanone (MEK)

bis(2-Chloroisopropyl)
Dichlorobenzene
Dichlorobiphenyl
1,2-Dichloroethane
Formaldehyde
Heptachlorobiphenyl
Hexachlorobenzene
Hexachlorobiphenyl
Hexaldehyde
Heptachlorodibenzo-p-dioxins
Monochlorobiphenyl
Monochlorophenol
n-Butyraldehyde
Octachlorodibenzo-p-dioxins
Pentachlorobenzene
Trichlorobenzene
Valderaldehyde

However, the following compounds were not changed as a result of the public comment. The EPA believes that the datapoints used to develop emission factors for these gaseous compounds are acceptable data. The EPA believes that the test reports used EPA accepted test methods, use representative wood residue fuel, and do not contain outliers.

Acrolein
Benzene
Benzo(b)fluoranthene
Benzo(j,k)fluoranthene
Benzoic acid
Chloroform
1,2-Dibromoethene
Fluoranthene
Fluorene
Hexachlorodibenzo-p-dioxins
Hydrogen Chloride
2-Nitrophenol
Perylene
Pyrene
Arsenic

Response: Emission factors for the following gaseous compounds were recalculated because EPA found that they included non-detect values that were greater than the detected values. Non-detect values are used in developing an emission factor but only when they are less

than detected values and, if used, one half of the detection limit is used to develop the emission factor. This EPA procedure is outlined in *Procedures For Preparing Emission Factor Documents*, U.S. EPA, EPA-454/R-95-015, November, 1997.

Acenaphthene, B138
Benzo(a)anthracene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Dibenzo(a,h)anthracene, B45
Indeno(1,2,3,c,d)pyrene
Phenol
Chromium (VI)

Response: The following gaseous compounds the commenter believes does not contain sufficient amount of data to calculate an accurate or representative emission factor. However, the EPA's policy is to use and report all available data at the time of the revisions, and to reflect data limitations in the quality rating that is assigned to each factor. Therefore, these factors were kept in the section.

Benzaldehyde
Benzo(e)pyrene
bis(2-Ethylhexyl)phthalate
Bromomethane
Dichloromethane
Hexanal
Isobutyraldehyde
2-Methylnaphthalene
Propanal
Propionaldehyde