PM Speciation Profiles (501, 502, 503, and 504) for Charbroiling and Cooking

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1 Introduction

PM speciation profiles assigned to cooking will be updated for use in the next $PM_{2.5}$ SIP. Currently, ARB does not have any PM speciation profiles for commercial cooking-related categories. Because of this the PM Profile 900 (unspecified) has been assigned to these categories for air quality modeling use.

Cooking-related sources are important contributors to total PM emissions. For year 2010, the statewide annual average $PM_{2.5}$ emitted from cooking-related sources is 25.2 tons/day, which is 2.8% of the total statewide $PM_{2.5}$ emissions; and the South Coast annual average $PM_{2.5}$ related to cooking is 14.8 tons/day, which is 11.8% of the total South Coast $PM_{2.5}$ emissions.

There are three cooking-related categories (EICs) in the current ARB emission inventory:

- 690-680-6000-0000 (Commercial Charbroiling);
- 690-682-6000-0000 (Deep Fat Frying); and
- 690-684-6000-0000 (Unspecified Cooking).

As illustrated in the pie chart (Figure 1) based on the 2010 statewide emission inventory, cooking-related PM emissions are mainly attributed to commercial charbroiling (77%), followed by unspecified cooking emissions (22%) and deep fat frying (1%).

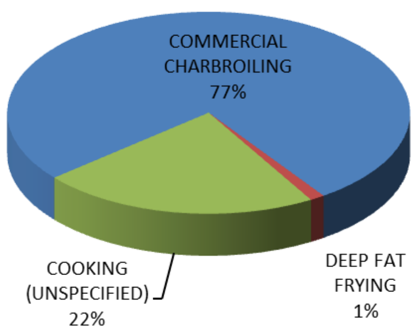

Figure 1. Pie chart of cooking-related categories

All cooking-relevant source tests that have been found in the literature correspond to profiles contained in U.S. EPA's SPECIATE 4.2[1] and the Desert Research Institute (DRI) Source Profiles Database[2] (Appendix 1). There are 78 cooking-related PM profiles in these two databases, but their profile structures and formats are different from ARB's. For example, ARB profiles use OM (organic matter) as a species while SPECIATE and the DRI profiles use OC (organic carbon); the total weight percentage of all species in the PM mass is 100% in the ARB profiles, which is not the case for some of the SPECIATE and DRI profiles (see Table A1 for details). Because of these important differences, the existing SPECIATE and DRI profiles cannot be used directly as ARB profiles; however, they can be compared, extracted, modified and composited with their original source testing data from peer-reviewed journal papers or reports to make speciation profiles for the three EICs described above.

Two different analysis techniques have been used to determine the proportion of elemental carbon (EC) and organic carbon (OC) contained in PM. These two analysis techniques, called IMPROVE and NIOSH, are used in both ambient air sampling and emissions source testing and they yield slightly different results which cannot be corrected with simple adjustment factors. As of 2009 the IMPROVE method officially replaced the NIOSH method which was commonly used prior to 2006.

Both the IMPROVE and NIOSH methods were used in collecting the available source testing data described above. For example, the IMPROVE method was used by DRI groups in their source tests [3-11], and the NIOSH method was used by Hildemann et al and Schauer et al [12-14]. Because these methods cannot be mixed, new profiles have been created for both. *However, this update will only assign the IMPROVE-based profiles to the inventory, since, as mentioned above, the IMPROVE method is now the official standard EC/OC measurement technique.* Updated NIOSH-based profiles have been developed *only* in case NIOSH-based air quality or emissions inventory analyses prior to 2009 are desired (e.g. source apportionment analyses using NIOSH-based air quality monitoring and these updated NIOSH-based profiles). ***NIOSH-based profiles will not be assigned to emission inventory categories***. The profiles developed under this update are listed below.

- PM Profile 501—Commercial charbroiling (IMPROVE);
- PM Profile 502—Cooking (IMPROVE);
- PM Profile 503—Commercial charbroiling (NIOSH);
- PM Profile 504—Cooking (NIOSH).

The IMPROVE-based PM Profile 501 will replace the currently assigned profile (Profile 900, *Unspecified)* for the category of commercial charbroiling (690-680-6000-0000) for all years and the IMPROVE-based PM Profile 502 will replace the currently assigned profile (Profile 900) for the categories of deep fat frying (690-682-6000-0000) and unspecified commercial cooking (690-684-6000-0000) for all years.

2 Methodology

In total, there are 47 cooking-related PM profiles in SPECIATE 4.2[1], and 31 cooking-related PM profiles in the DRI database[2] were developed. Some of the profiles are made based on individual source tests, and others are composite profiles of a group of source tests. All of these profiles or test data consist of the essential species needed for ARB PM modeling, and these species include OC, EC, sulfate, and nitrate.

2.1 Within the two profile databases, 14 profiles overlap (SPECIATE 4.2 No. 3643 – 4111 vs. DRI 08081 – 16098). These profiles are based on the Imperial Valley/Mexicali Cross Border PM10 Transport Study[10], Northern Front Range Air Quality Study[7-9], and other studies conducted by DRI in Mexico City between 1997 and 2002[4-6]. Since all of these tests were performed in Mexico, they are not used to develop ARB's California-specific PM profiles.

2.2 SPECIATE 4.2 Profiles 4334 to 4382 are normalized versions of DRI Profiles 19131 to 19179, respectively. Some of the profiles were generated based on individual source tests and others are based on composites of individual source test data. Source tests were conducted by DRI at the University of California, Riverside's CE-CERT facility in 2000[11]. For these source tests, the cooking exhaust was ducted through a baffle-type grease extractor in a ventilation hood, and the exhaust stream was mixed with 25-28 times its volume of clean air using a dilution chamber. There were 12 tests conducted in this study, which consisted of the following 5 kinds of cooking operations:

Table 1. Summary of SPECIATE4.2 Profiles 4334-4382

	Operation	*Meat*	*Cooker*	*Fuel*	*Profile No.*	
					SPECIATE 4.2	*DRI*
1	smoking	chicken	charbroiler	Charcoal/ mesquite wood	4334-4336	19191-19133
2	cooking	chicken	charbroiler	charcoal	4337-4338	19134-19135
3	cooking	chicken	charbroiler	propane/ lava rock	4339-4342	19136-19139
4	cooking	hamburger	charbroiler	charcoal	4343-4344	19140-19141
5	stirfrying	steak	stove	propane	4345	19142

The SPECIATE Profiles 4379 to 4382 are composite profiles for the first four operations (i.e. smoking chicken, charbroiling chicken with charcoal, charbroiling chicken with propane and charbroiling hamburger, respectively). The weight percentages of each species in these profiles have been normalized by the total gravimetric mass of the measured species. These profiles are different from the DRI composite profiles 19176 to 19179, but are identical to the profiles in Chow et al.'s paper[11]. In these normalized profiles, the OC instead of OM was used to calculate the total mass for normalization. This is different from what is done for ARB's PM profiles in that OM is used for calculating the total mass for normalization. Therefore, modifications need to be made to convert the composite profiles 4379 to 4382, and 4345 to ARB format profiles. The following steps are used to implement these modifications:

1. Convert OC in the above profiles to OM. The most common elemental analyses for PM quantifies OC, which is typically multiplied by a constant conversion factor, an OM/OC ratio, to estimate OM for assessing total PM mass. A factor of 1.4 is traditionally used[15].
2. The PM species 'others' is created to capture the mass associated with the five geological elements (i.e. Al, Si, Ca, Fe and Ti). using the formula of
$$0.89\times[Al]+1.14\times[Si]+0.40\times[Ca]+0.43\times[Fe]+0.67\times[Ti]$$
where [Al], [Si], [Ca], [Fe] and [Ti] are weight percentages of these five elements, respectively[16].

3. Add the species of non-sulfate sulfur (non-SO_4 S), insoluble chlorine (insol-Cl), and insoluble potassium (insol-K) to avoid double-counting mass[16] because both sulfate and sulfur, chloride and chlorine, and potassium ion and potassium exist in the same profile. Resulting negative values are set to zero.
    - Non-sulfate sulfur (non-SO_4 S), i.e., total sulfur (S) minus the portion of sulfur in sulfate (SO_4) replaces the total sulfur entry.
      $[\text{non-}SO_4\ S] = [S] - [SO_4^{2-}] * (32/96)$
    - Insoluble chlorine (insol-Cl), i.e., total chlorine (Cl) minus chloride ion (Cl^-) replaces the total chlorine entry.
      $[\text{insol-Cl}] = [Cl] - [Cl^-]$
    - Insoluble potassium (insol-K), i.e., total potassium (K) minus potassium ion (K^+) replaces the total potassium entry.
      $[\text{insol-K}] = [K] - [K^+]$
4. Add up the weight percentages of all the species as the total percentage of the mass. Please note that OM and ‘others’ need to be added for the total mass, but [S], [Cl], and [K] are not included.
5. Divide the weight percentage of each species by the total percentage of the mass to get the normalized speciation profile.

2.3 SPECIATE 4.2 Profiles 4554 (meat charbroiling emissions)[13], 4653-4655 (cooking vegetables)[14], and 160002.5 and 160012.5 (meat cooking)[12] were based on Schauer et al. and Hildemann et al.’s source testing data, which were collected from a local commercial-scale kitchen. The diluted PM exhaust generated during the cooking was sampled through an overhead exhaust hood equipped with a baffle-type grease extractor [12-14]. These profiles are not included in the DRI database. Profile 4554 is an average profile of two charbroiling tests of frozen and thawed hamburger patties[13]; Profile 160002.5 is made based on tests of charbroiling hamburger over a natural gas flame[12]; Profile 160012.5 is made based on tests of frying meat[12]; Profiles 4653 to 4655 are based on stir-frying vegetables, but, since the speciation is incomplete in the related source tests, they are not used for profile development in this work. Profiles 4554, 160002.5 and 160012.5 are used to generate ARB format profiles using the following steps, which are similar to those described in section 2.2:

1. Convert OC to OM by multiplying the OM/OC conversion factor of 1.4;
2. Calculate the weight percentage for species ‘others’;
3. Calculate the weight percentage for ‘non-SO_4 S’ and ‘insol-Cl’ to avoid double-counting mass[16]. No double-counting problem for ‘K’ because no ‘K^+’ is reported in these profiles;
4. Add up the weight percentages of all the species as the total percentage of the mass;
5. Divide the weight percentage of each species by the total percentage of the mass to get the normalized speciation profile.

It is important to note that two different techniques were employed for the analysis of EC and OC in the PM samples for the source tests mentioned above. The IMPROVE EC/OC method was used by DRI groups in their source tests[3-11] , and the NIOSH EC/OC method was used by Hildemann et al and Schauer et al[12-14]. Research has suggested that the measurements obtained from these two methods should not be integrated because improper compositing or integration will lead to biases and errors in source attribution studies[17]. Therefore, two sets of speciation profiles are developed based on their EC/OC analytical methods.

In summary, the profiles or tests used for developing ARB profiles consist of (Table 2):

Table 2. Profiles in SPECIATE and DRI Database Used for ARB Profile Development

	ECOC method	*Profile Type*	*Operation*	*Profiles*	
				SPECIATE 4.2	*DRI*
1	IMPROVE	average	Smoking chicken w/wood	4379[11]	19176
2	IMPROVE	average	Charbroiling chicken w/ charcoal	4380[11]	19177
3	IMPROVE	average	Charbroiling chicken w/propane	4381[11]	19178
4	IMPROVE	average	Charbroiling hamburger w/charcoal	4382[11]	19179
5	IMPROVE	single	Stirfrying steak w/propane	4345[11]	19142
6	NIOSH	average	Charbroiling hamburger w/natural gas	4554[13]	N/A
7	NIOSH	average	Charbroiling hamburger w/natural gas	160002.5[12]	N/A
8	NIOSH	average	Frying meat	160012.5[12]	N/A

3 Results and Discussion

According to the emission inventory needs, the profiles modified above can be further composited into a charbroiling profile and a cooking profile.

For the IMPROVE EC/OC method: the charbroiling profile (#501) is the average of the 3 charbroiling-related profiles, and the cooking profile (#502) is the average of the 3 charbroiling-related profiles, the 1 smoking profile and the 1 stir-frying profile.

For the NIOSH EC/OC method: the charbroiling profile (#503) is the average of the 2 charbroiling-related profiles; and the cooking profile (#504) is the average of the 2 charbroiling-related profiles and the 1 frying meat profile.

In general, OM is the dominant species. More specifically, in the four composite profiles, OM is over 90% of the total PM mass. EC is 4.8% and 6.3% in the IMPROVE profiles, but not detected in the NIOSH profiles.

A new SAROAD code needs to be added to the existing PMSPECIES file for sodium ion (Table 3).

Table 3. New ARB SAROAD Codes to be Added to the PMSPECIES File

ARB SAROAD	CAS	Chemical Name	Formula	Molecular Weight
12181	N/A	Sodium ion	Na^+	23

Table 4. Cooking-Related PM2.5 Speciation Profiles

Profile No.		501		502	
Profile Name		Charbroiling (IMPROVE)		Cooking (IMPROVE)	
Species	SAROAD	Weight Percentage (%)	*Standard Deviation*	Weight Percentage (%)	*Standard Deviation*
OM	11102	93.263039	*5.297720*	90.683463	*6.659517*
EC	12000	4.814265	*3.968611*	6.288829	*4.710758*
sulfate	12403	0.221409	*0.179164*	0.214067	*0.191746*
non-sulfate sulfur	12404	0.049262	*0.040751*	0.101140	*0.094678*
nitrate	12306	0.059127	*0.004556*	0.262678	*0.305320*
chloride ion	12203	0.204499	*0.292946*	0.513030	*0.513212*
insoluble chlorine	12202	0.014653	*0.019909*	0.084534	*0.165174*
ammonium	12301			0.029168	*0.065221*
sodium ion	12181	0.146716	*0.125832*	0.131486	*0.119387*
sodium	12184				
potassium ion	65312	0.090440	*0.081055*	0.123256	*0.142052*
insoluble potassium	12182	0.028281	*0.013391*	0.060485	*0.056456*
potassium	12180				
magnesium	12140	0.101334	*0.151172*	0.109528	*0.108791*
aluminum	12101	0.034624	*0.021800*	0.050570	*0.031352*
silicon	12165	0.237446	*0.193869*	0.313526	*0.189264*
phosphorus	12152	0.004644	*0.003858*	0.003074	*0.003510*
calcium	12111	0.111749	*0.052537*	0.143956	*0.060570*
titanium	12161	0.002625	*0.001286*	0.004726	*0.003441*
vanadium	12164	0.000121	*0.000150*	0.000194	*0.000259*
chromium	12112	0.001229	*0.001944*	0.001926	*0.002310*
manganese	12132	0.008338	*0.001839*	0.016558	*0.020236*
iron	12126	0.120164	*0.056486*	0.205100	*0.202892*
cobalt	12113	0.000969	*0.000797*	0.000956	*0.000696*
nickel	12136	0.003065	*0.001422*	0.003867	*0.001565*
copper	12114	0.008421	*0.004828*	0.017527	*0.021454*
zinc	12167	0.015953	*0.012269*	0.024623	*0.016106*
gallium	12124			0.000076	*0.000169*
arsenic	12103	0.000121	*0.000041*	0.000406	*0.000707*
selenium	12154	0.000025	*0.000043*	0.000045	*0.000067*
bromine	12109	0.000875	*0.000343*	0.004751	*0.007043*
rubidium	12176	0.000171	*0.000153*	0.000254	*0.000310*
strontium	12168	0.000796	*0.000639*	0.000936	*0.000493*
zirconium	12185	0.007745	*0.013415*	0.005464	*0.010091*
palladium	12151	0.000245	*0.000308*	0.001535	*0.002655*
silver	12166	0.002092	*0.003624*	0.002980	*0.003050*
cadmium	12110	0.000172	*0.000238*	0.000436	*0.000711*
indium	12131	0.000833	*0.001011*	0.000636	*0.000801*
tin	12160	0.001113	*0.000801*	0.001667	*0.002004*
antimony	12102	0.001805	*0.001481*	0.012950	*0.025963*
barium	12107	0.016896	*0.017090*	0.011515	*0.014362*
lanthanum	12146	0.009045	*0.011674*	0.005427	*0.009627*
gold	12143	0.000935	*0.001620*	0.000561	*0.001255*
mercury	12142			0.000045	*0.000102*
thallium	12173			0.000015	*0.000034*
lead	12128	0.015129	*0.026205*	0.010667	*0.019712*
others	12999	0.399633	*0.253400*	0.551368	*0.307153*
total		*100.000000*		*100.000000*	

Profile No.		503		504	
Profile Name		Charbroiling (NIOSH)		Cooking (NIOSH)	
Species	SAROAD	Weight Percentage (%)	*Standard Deviation*	Weight Percentage (%)	*Standard Deviation*
OM	11102	96.143270	*0.151345*	93.674473	*4.277420*
EC	12000				
sulfate	12403	0.122495	*0.173234*	0.416617	*0.523954*
non-sulfate sulfur	12404	0.193233	*0.273272*	0.584015	*0.703897*
nitrate	12306	0.398132	*0.530046*	1.031029	*1.158512*
chloride ion	12203	0.388717	*0.060716*	1.554789	*2.020151*
insoluble chlorine	12202				
ammonium	12301				
sodium ion	12181				
sodium	12184	0.510457	*0.342429*	0.505941	*0.242260*
potassium ion	65312				
insoluble potassium	12182				
potassium	12180	0.439115	*0.357026*	0.425252	*0.253595*
magnesium	12140	0.530813	*0.750682*	0.353875	*0.612930*
aluminum	12101	0.086328	*0.009901*	0.057552	*0.050331*
silicon	12165	0.147559	*0.027197*	0.098373	*0.087337*
phosphorus	12152	0.125454	*0.012434*	0.083636	*0.072963*
calcium	12111	0.043419	*0.032638*	0.084158	*0.074241*
titanium	12161	0.005833	*0.008249*	0.003889	*0.006735*
vanadium	12164	0.001750	*0.002475*	0.001167	*0.002021*
chromium	12112			0.055212	*0.095630*
manganese	12132			0.015091	*0.026139*
iron	12126	0.051585	*0.044187*	0.122729	*0.127125*
cobalt	12113				
nickel	12136	0.014253	*0.008608*	0.027538	*0.023802*
copper	12114	0.198326	*0.280475*	0.132217	*0.229007*
zinc	12167	0.128328	*0.181484*	0.085552	*0.148181*
gallium	12124				
arsenic	12103	0.001167	*0.001650*	0.000778	*0.001347*
selenium	12154	0.000583	*0.000825*	0.002597	*0.003537*
bromine	12109	0.005250	*0.007424*	0.034419	*0.050794*
rubidium	12176			0.033127	*0.057378*
strontium	12168	0.002333	*0.003300*	0.005236	*0.005543*
zirconium	12185				
palladium	12151				
silver	12166	0.010170	*0.014383*	0.006780	*0.011743*
cadmium	12110				
indium	12131				
tin	12160				
antimony	12102				
barium	12107	0.137002	*0.136220*	0.260652	*0.234831*
lanthanum	12146	0.010170	*0.014383*	0.006780	*0.011743*
gold	12143				
mercury	12142				
thallium	12173				
lead	12128	0.015749	*0.022273*	0.084116	*0.119457*
others	12999	0.288507	*0.015390*	0.252409	*0.063464*
total		*100.000000*		*100.000000*	

Two assumptions related to these profiles are proposed in this work:

- The ratios of PM_{10}/TPM and $PM_{2.5}$/TPM for the default PM Profile 900 are 0.70 and 0.42, respectively. It is possible that the $PM_{2.5}$ emissions from charbroiling or cooking are underestimated as testing in the South Coast Air Basin has demonstrated that most of the PM_{10} emissions are equal to or less than 2.5 microns. Also because filters are typically used in the ventilation hood during cooking, it is expected that the majority of the TPM is PM_{10}. So for these charbroiling and cooking profiles, the ratios of PM_{10}/TPM and $PM_{2.5}$/TPM are assumed to be 1.0.
- The tests and profiles discussed above are all based on source testing for $PM_{2.5}$ exhaust. No speciation information for PM_{10} and total PM (TPM) has been found in the above source tests. Therefore, it is suggested to use the same speciation profiles for cooking-related PM_{10} and TPM exhausts for now (i.e. assume all of the emissions mass has the same species mix).

4 Estimated Impacts of Changes on Emission Inventory

This update will only assign the IMPROVE-based profiles to the inventory, since the IMPROVE method is now the official standard EC/OC measurement technique. NIOSH-based profiles will not be assigned to emission inventory categories. Although the technique is outdated, updated NIOSH-based profiles have been developed in case air quality or emissions inventory analyses prior to 2009 are desired (e.g. source apportionment analysis).

The newly-developed IMPROVE-based profiles will replace the current Profile 900 for the three cooking-related categories: PM Profile 501 (Charbroiling-IMPROVE) for Commercial Charbroiling category (i.e. 690-680-6000-0000), and PM Profile 502 (Cooking-IMPROVE) for Unspecified Cooking category (i.e. 690-684-6000-0000). Since there is currently no source test data or profile available for deep fat frying operations, and emissions from deep frying are only estimated at around 1% of the cooking emissions, it is suggested that the composite cooking Profile 502 be assigned to this category (i.e. 690-682-6000-0000).

Since Profile 900 is currently being used as a default profile for these categories, no detailed species can be segregated for these categories. Using Profiles 501 and 502 to replace Profile 900, the changes in PM modeling species for year 2010 emission are estimated in Table 5. Given the 2010 statewide annual average commercial cooking emissions of 25.23 tons/day [18], the OM increases from 0 to 23.37 tpd, EC increases from 0 to 1.30 tpd, sulfate increases from 0 to 0.05 tpd, and nitrate increases from 0 to 0.03 tpd. Commensurately, the emission of ‘other species’ decreases from 25.23 tpd to 0.47 tpd because the PM mass is now assigned to specific species.

Table 5. Changes on 2010 Statewide Annual Ave. Emissions Using Updated Cooking Profiles (tpd)

	Current (PM No. 900)	New (PM No. 501 & 502)	Change
OM	0	23.37	+23.37
EC	0	1.30	+1.30
Sulfate	0	0.05	+0.05
Nitrate	0	0.03	+0.03
Other species	25.23	0.47	-24.76

Because NIOSH EC/OC method is not in use for ambient PM monitoring, the newly-developed NIOSH profiles, PM Profiles 503 (Charbroiling-NIOSH) and 504 (Cooking-NIOSH) will not be used for air quality modeling purpose as the above IMPROVE profiles. They are recommended to be used only in source apportionment studies in which EC/OC for ambient and other emission sources is measured by NIOSH method.

5 Version Control

This section will be completed after management approval and after the CEIDARS FRACTION table and PMPROFILE table are updated. Version information from CEIDARS FRACTION table will be copied here.

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Appendix 1. Summary of Cooking-Related PM Speciation Profiles in SPECIATE 4.2 and DRI Source Profile Database

Table A1. Cooking-related PM Speciation Profiles in SPECIATE 4.2 and DRI Database

SPECIATE 4.2	DRI Database	Profile Notes	Total % in DRI Database	Total % in SPECIATE 4.2
Same Profiles in SPECIATE 4.2 and DRI Database:				
3643	08081	Composite of 11 Mexicali charbroil cooking emission profiles from the Asadero El Nerivl Ciclon restaurant (IMTSA1, IMTSA2, IMTSA3, IMTSA4, IMTSA5, IMTSA6, IMTSA7, IMTSA8, IMTSA9, IMTSA0, and IMTSAA). Samples collected on 12/16/92 – 12/18/92.	70.768	70.768
3644	08082	Composite of nine Mexicali charbroil cooking emission profiles from the La Cabana Asadero restaurant (IMTSC1, IMTSC2, IMTSC3, IMTSC4, IMTSC5, IMTSC6, IMTSC7, IMTSC8, and IMTSC9). Samples collected on 12/18/92.	80.7343	80.7343
Chow, J.C.; Watson, J.G. (1997). Imperial Valley/Mexicali Cross Border PM10 Transport Study. Report No. 4692.1D1. Prepared for U.S. Environmental Protection Agency, Region IX, San Francisco, CA, by Desert Research Institute, Reno, NV.				
3915	13050	Composite of NMCH, NMAHa, NMCK, and NMCCa.	83.729	83.729
3916	13051	Average of three replicate samples, automated charbroiler, hamburger, samples MAH1, 2, and 3.	83.8692	83.8692
3917	13052	Charbroiled hamburger, sample MCH1.	83.6959	83.6959
3918	13053	Average of two samples, charbroiled chicken w/ skin, samples MCC1 and MCC2.	83.4128	83.4128
3919	13054	Charbroiled steak, sample MCK1.	83.9417	83.9417
Zielinska, B.; McDonald, J.D.; Hayes, T.; Chow, J.C.; Fujita, E.M.; Watson, J.G. (1998). Northern Front Range Air Quality Study, Volume B: Source measurements. Prepared for Colorado State University, Fort Collins, CO, by Desert Research Institute, Reno, NV. http://charon.cira.colostate.edu/DRIFinal/ZipFiles/. Fujita, E.M.; Watson, J.G.; Chow, J.C.; Robinson, N.F.; Richards, L.W.; Kumar, N. (1998). Northern Front Range Air Quality Study. Volume C: Source apportionment and simulation methods and evaluation. Prepared for Colorado State University, Cooperative Institute for Research in the Atmosphere, Ft. Collins, CO, by Desert Research Institute, Reno, NV. http://charon.cira.colostate.edu/DRIFinal/ZipFiles/. Watson, J.G.; Fujita, E.M.; Chow, J.C.; Zielinska, B.; Richards, L.W.; Neff, W.D.; Dietrich, D. (1998). Northern Front Range Air Quality Study. Final report. Prepared for Colorado State University, Fort Collins, CO, by Desert Research Institute, Reno, NV. http://charon.cira.colostate.edu/DRIFinal/ZipFiles/.				
4020	16007	Composite of two food cooking profiles CET1 and CET 2.		81.2814
4048	16035	Composite of two food cooking profiles. Grilled chicken shop, Lindavista District, Mexico City. LPG fuel. Sample collection time 1000 - 1135 and 1521- 1611 (3/15/98).	82.2964	82.2964
4052	16039	Composite of two food cooking profiles. Restaurant "San Antonio", Del Valle District, Mexico City. Charcoal and LPG fuels. Sample collection time 1600 - 1800 and 1820- 1950 (3/13/98).	79.5065	79.5065
4108	16095	Food cooking profile from restaurant "El Torito", Lindavista District, Mexico City. Fried pork. LPG fuel. Sample collection time 1200 – 1245 (3/15/98).	83.262	83.262

4109	16096	Food cooking profile from restaurant "El Torito", Lindavista District, Mexico City. Fried pork. LPG fuel. Sample collection time 1307- 1437 (3/15/98).	79.3009	79.3009
4110	16097	Cooking profile from a restaurant on 27th St (3/15/98).	73.3569	73.3569
4111	16098	Composite of two food cooking profiles. Corn tortilla making. LPG fuel. Sample collection time 0825-1125 and 1820-1950 (3/14/98).	81.7725	81.7725

Vega, E.; Reyes, E.; Ruiz, H.; Garcia, J.; Sanchez, G.; Martinez-Villa, G.; Gonzalez, U.; Chow, J.C.; Watson, J.G. (2004). Analysis of PM2.5 and PM10 in the atmosphere of Mexico City during 2000-2002. Journal of the Air & Waste Management Association, in press.

Chow, J.C.; Watson, J.G.; Edgerton, S.A.; Vega, E. (2002). Chemical composition of PM10 and PM2.5 in Mexico City during winter 1997. Science of the Total Environment 287 (3), 177-201.

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Original Profiles in DRI Database, and Normalized in SPECIATE 4.2

4334	19131	Emissions from smoking chicken on an underfired charcoal charbroiler with mesquite wood smoke were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/22/00.	69.6521	100
4335	19132	Emissions from smoking chicken on an underfired charcoal charbroiler with mesquite wood smoke were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/22/00.	87.6608	100
4336	19133	Emissions from smoking chicken on an underfired charcoal charbroiler with mesquite wood smoke were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/22/00.	81.0982	100
4337	19134	Emissions from cooking chicken on an underfired charcoal charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/23/00.	68.8305	100
4338	19135	Emissions from cooking chicken on an underfired charcoal charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/23/00.	75.9677	100
4339	19136	Emissions from cooking chicken on an underfired propane/lava rock charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/23/00.	74.767	100
4340	19137	Emissions from cooking chicken on an underfired propane/lava rock charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/23/00.	83.9041	100
4341	19138	Emissions from cooking chicken on an underfired propane/lava rock charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/23/00.	91.3645	100
4342	19139	Emissions from cooking chicken on an underfired propane/lava rock charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/23/00.	100	100
4343	19140	Emissions from cooking hamburger on an underfired charcoal charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/24/00.	74.1264	100
4344	19141	Emissions from cooking hamburger on an underfired charcoal charbroiler were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/24/00.	72.3119	100
4345	19142	Emissions from stirfrying steak and peppers on a 24" x 26" propane-gas-fueled commercial stove were collected in a fume hood at the University of California–Riverside's CE-CERT facility on 02/24/00.	143.740	100
4379	19176	Composite of three profiles of emissions from smoking chicken on an	79.4701	100

		underfired charcoal charbroiler with mesquite wood smoke (SMOCKN01, SMOCKN02, and SMOCKN03).		
4380	19177	Composite of two profiles of emissions from cooking chicken on an underfired charcoal charbroiler (CHACKN01 and CHACKN02).	72.3998	100
4381	19178	Composite of four profiles of emissions from cooking chicken on an underfired propane/lava rock charbroiler (PROCKN01, PROCKN02, PROCKN03, and PROCKN04).	83.3454	100
4382	19179	Composite of two profiles of emissions from cooking hamburger on an underfired charcoal charbroiler (CHAHAM01 and CHAHAM02).	73.2196	100
Chow, J.C.; Watson, J.G.; Kuhns, H.D.; Etyemezian, V.; Lowenthal, D.H.; Crow, D.J.; Kohl, S.D.; Engelbrecht, J.P.; Green, M.C. (2004). Source profiles for industrial, mobile, and area sources in the Big Bend Regional Aerosol Visibility and Observational (BRAVO) Study. Chemosphere 54 (2), 185-208.				
In DRI Database Only				
	19180	Composite of 19177 (charcoal chicken), 19178 (propane chicken), and 19179 (charcoal hamburger) profiles	76.3214	
See 19177, 19178 and 19179.				
in SPECIATE 4.2 Only				
4383		Composite of 12 profiles of cooking emissions (SMOCKN01, SMOCKN02, SMOCKN03, CHACKN01, CHACKN02, PROCKN01, PROCKN02, PROCKN03, PROCKN04, CHAHAM01, CHAHAM02, and STIFRY01).		100
See 4334-4382				
4554		Meat charbroiling emissions--Species are the composite average of the two charbroiler tests of frozen and thawed hamburger patties from the denuded sampling train. Several alkanes and PAH were quantified in the first backup PUF cartridge, indicating negative artifacts of those specie		35.51
Schauer, J.J., M.J. Kleeman, G.R. Cass, and B.R.T. Simoneit (1999). Measurement of Emissions from Air Pollution Sources. 1. C1-C29 Organic Compounds from Meat Charbroiling. Environmental Science and Technology, vol. 33, no. 10, pp. 1566-1577.				
4653		Cooking vegetables - Stir frying in soybean oil		79.36
4654		Cooking vegetables - Stir frying in canola oil		61.7
4655		Cooking potatoes - Deep frying in hydrogenated oil		66.7
Schauer, J.J., M.J. Kleeman, G.R. Cass, and B.R.T. Simoneit (2002). Measurement of Emissions from Air Pollution Sources. 4. C1-C27 Organic Compounds from Cooking with Seed Oils. Environmental Science and Technology, vol. 36, no. 4, pp. 567 - 575.				
160002.5		Meat Cooking--Charbroiling-- local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		61.94
160012.5		Meat Cooking -- Frying: A local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		66.2
Hildemann, L.M.; Markowski, G.R.; Cass, G.R.; "Chemical Composition of Emissions from Urban Sources of Fine Organic Aerosol"; Environ. Sci. Technol. Vol. 25, No. 4, p. 744, 1991.				
91005		Charbroiling - Composite--Median of Profiles 160002.5, 3915, 4383, and 4554.		86.76
92015		Charbroiling - Simplified based on Composite Profile #91005		100
92046		Meat Frying--Simplified based on Individual Profile #160012.5		100

92058		Potato Deep Frying--Simplified based on Individual Profile #4655		100
1600030		Meat Cooking - Charbroiling: A local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		0
16000C		Meat Cooking - Charbroiling: A local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		0
1600110		Meat Cooking - Frying: A local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		0
1600130		Meat Cooking - Frying: A local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		0
16001C		Meat Cooking -- Frying: A local commercial-scale kitchen was utilized in conducting this experiment. Two types of hamburger meat, regular (approximately 21% fat) and extra-lean (approximately 10% fat) were cooked.		0