



## **APPENDIX AVAILABLE ON REQUEST**

### **Research Report 133**

#### **Characterization of Metals Emitted from Motor Vehicles**

##### **Appendix C. Brake and Tire Wear Emissions**

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This document was reviewed by the HEI Health Review Committee but did not undergo the HEI scientific editing and production process.

### APPENDIX C

#### DYNAMOMETER TESTS, concentrations in the chamber in vehicle tests and blank tests

<b>PM10</b>		VEHICLE	EXTERNAL			mass	OC	EC	sulfate	nitrate	chloride	ammonium
TEST*	VEH	ENGINE RUNNING	ENGINE FAN ON	DYNO RUNNING	TYPE	ug/m3 AVG SD	ug/m3 AVG SD	ug/m3 AVG SD	ug/m3 AVG SD	ug/m3 AVG SD	ug/m3 AVG SD	ug/m3 AVG SD
FTP 1A	A	Y	Y	Y	FTP	70 4						
UC A	A	Y	Y	Y	UC	166 4	74.52 7.51	5.12 0.85	2.20 0.44	0.0 0.44	0.00 0.58	0.37 0.30
Blank 1	A	N	N	Y	BLANK	21 4	19.88 3.82	0.23 0.59	2.52 0.44	0.0 0.44	0.00 0.59	0.43 0.30
SS A	A	Y	Y	Y	30MPH	71 4						
FTP 2A	A	Y	Y	Y	FTP	70 4	25.60 4.16	0.43 0.59	2.02 0.43	0.0 0.43	0.00 0.58	0.89 0.30
Blank 2	B	N	Y	N	BLANK	7 4	18.74 3.76	0.25 0.60	2.52 0.43	0.72 0.43	0.78 0.58	0.0 0.30
FTP 1B	B	Y	Y	Y	FTP	90 4						
UC B	B	Y	Y	Y	UC	336 4	76.04 7.45	6.99 0.96	11.75 0.42	2.05 0.42	0.87 0.56	0.77 0.29
Blank 3	B	N	N	Y	BLANK	10 4	19.95 3.75	0.08 0.58	1.76 0.43	0.0 0.43	0.00 0.57	0.73 0.29
SS B	B	Y	Y	Y	30MPH	35 4						
FTP 2B	B	Y	Y	Y	FTP	139 4	36.49 5.07	1.43 0.67	8.82 0.43	0.76 0.43	0.00 0.58	0.89 0.30
<b>PM2.5</b>												
FTP 1A	A	Y	Y	Y	FTP	61 5	20.26 3.02	0.41 0.48	1.97 0.33	0.0 0.33	0.00 0.45	2.66 0.30
UC A	A	Y	Y	Y	UC	132 4	62.87 5.34	4.01 0.67	1.98 0.34	0.33 0.34	0.32 0.45	2.95 0.69
Blank 1	A	N	N	Y	BLANK	21 6	15.91 2.77	0.17 0.46	2.31 0.33	0.08 0.33	0.00 0.45	3.12 0.69
SS A	A	Y	Y	Y	30MPH	49 6	20.99 3.06	0.25 0.47	1.40 0.33	0.36 0.33	0.00 0.45	2.21 0.69
FTP 2A	A	Y	Y	Y	FTP	47 2	21.96 3.08	0.28 0.46	1.77 0.33	0.0 0.33	0.00 0.44	2.33 0.68
Blank 2	B	N	Y	N	BLANK	12 11	16.03 2.76	0.15 0.46	2.31 0.33	0.33 0.33	0.38 0.44	3.54 0.69
FTP 1B	B	Y	Y	Y	FTP	58 5	24.29 3.21	0.86 0.50	4.61 0.34	0.36 0.34	0.38 0.45	6.00 0.69
UC B	B	Y	Y	Y	UC	241 4	65.13 5.26	3.45 0.63	8.51 0.33	0.54 0.33	0.55 0.43	10.15 0.67
Blank 3	B	N	N	Y	BLANK	0 3	16.76 2.74	0.25 0.46	1.49 0.33	0.05 0.33	0.00 0.44	6.54 0.69
SS B	B	Y	Y	Y	30MPH	29 3	23.23 3.16	0.29 0.46	3.06 0.33	0.05 0.33	1.10 0.44	6.02 0.69
FTP 2B	B	Y	Y	Y	FTP	96 3	28.01 3.38	1.35 0.52	6.16 0.33	0.48 0.33	0.47 0.44	7.43 0.68

\* SEE CHAPTER 3 FOR COMPLETE DESCRIPTIONS OF DYNAMOMETER TEST CONDITIONS

**DYNAMOMETER TESTS, concentrations in the chamber in vehicle tests and blank tests**

<b>PM10</b>	<b>Na</b>		<b>Mg</b>		<b>Al</b>		<b>K</b>		<b>Ca</b>		<b>Ti</b>		<b>V</b>		<b>Cr</b>		<b>Mn</b>		<b>Fe</b>		
	<b>sodium</b>		<b>magnesium</b>		<b>aluminum</b>		<b>potassium</b>		<b>calcium</b>		<b>titanium</b>		<b>vanadium</b>		<b>chromium</b>		<b>manganese</b>		<b>iron</b>		
<b>TEST*</b>	ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		
	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	
<b>FTP 1A</b>																					
<b>UC A</b>	1544.3	259.3	340.8	21.2	1162.7	75.6	569.5	57.0	332.3	34.9	44.9	3.1	12.97	0.72	8.49	0.80	64.19	3.41	13771	690	
<b>Blank 1</b>	2507.8	322.7	100.6	5.4	1480.3	84.1	723.5	66.1	318.6	20.2	30.6	3.0	2.73	0.18	3.01	0.32	4.82	0.57	334	17	
<b>SS A</b>																					
<b>FTP 2A</b>	2333.8	318.3	537.3	32.9	1499.6	106.0	721.3	65.1	350.2	58.5	47.1	3.5	13.16	0.66	15.12	0.78	82.57	4.59	18865	1011	
<b>Blank 2</b>	1642.0	220.8	62.8	3.4	1106.0	66.8	555.9	47.3	185.8	16.5	26.3	3.5	2.78	0.25	0.00	0.41	4.22	0.70	212	11	
<b>FTP 1B</b>																					
<b>UC B</b>	2575.0	230.5	1115.4	62.3	1951.4	102.6	1445.2	81.3	1710.3	91.6	279.1	14.4	14.88	0.76	156.97	8.12	481.65	24.90	49404	2894	
<b>Blank 3</b>	1936.9	259.2	81.7	7.1	1303.2	75.5	630.3	50.2	265.9	15.1	69.1	17.3	2.70	0.59	0.00	0.82	9.23	2.94	171	11	
<b>SS B</b>																					
<b>FTP 2B</b>	2311.0	265.8	764.4	42.6	2023.9	112.1	1024.5	67.6	944.4	57.1	191.9	9.7	10.79	0.58	94.07	4.87	279.40	15.30	36705	1866	
<b>PM2.5</b>																					
<b>FTP 1A</b>	1211.6	156.3	261.2	13.2	790.3	45.3	391.1	32.4	165.4	15.1	32.5	3.9	11.89	0.62	7.35	0.38	54.31	2.89	11873	641	
<b>UC A</b>	1741.3	190.3	249.3	13.1	1060.0	57.7	506.0	37.0	200.1	12.4	27.8	3.0	9.84	0.52	9.34	0.60	60.39	3.11	13352	693	
<b>Blank 1</b>	1555.5	295.4	72.2	3.7	1058.3	62.9	467.6	54.1	170.8	9.8	19.7	2.3	1.62	0.10	0.52	0.14	2.13	0.14	180	9	
<b>SS A</b>																					
<b>FTP 2A</b>	871.1	76.7	266.8	14.8	600.3	31.3	323.7	19.6	350.1	21.0	35.2	3.7	7.78	0.45	5.99	0.62	46.56	2.66	10751	553	
<b>Blank 2</b>	1708.8	209.4	59.0	3.4	1077.7	60.1	509.7	44.1	126.7	13.8	16.6	1.9	2.80	0.17	0.09	0.20	2.88	0.19	217	11	
<b>FTP 1B</b>																					
<b>UC B</b>	1483.1	144.8	279.3	14.6	1207.2	70.2	585.5	39.8	423.7	36.0	86.2	20.0	4.85	0.74	46.97	2.45	102.95	5.76	14215	715	
<b>UC B</b>	1873.6	166.6	1316.9	67.5	1996.4	105.7	1178.0	67.9	1508.6	79.6	288.3	14.7	12.35	0.66	183.59	9.35	553.01	28.18	44225	2225	
<b>Blank 3</b>	1839.5	169.9	48.4	2.9	1121.4	63.2	540.4	35.4	252.1	20.9	14.3	1.5	1.43	0.07	0.00	0.16	2.25	0.25	135	8	
<b>SS B</b>																					
<b>FTP 2B</b>	1537.2	170.3	98.7	5.5	1034.1	59.3	478.6	33.0	264.8	16.7	75.9	5.9	3.13	0.16	9.42	0.57	21.03	1.15	2806	146	
<b>FTP 2B</b>	1160.7	142.2	197.3	11.7	789.9	47.0	464.7	37.1	473.3	33.9	62.7	3.5	5.21	0.28	26.48	1.40	82.49	4.22	11204	575	

DYNAMOMETER TESTS, concentrations in the chamber in vehicle tests and blank tests

TEST*	Cu copper		Zn zinc		As arsenic		Rb rubidium		Sr strontium		Mo molybdenum		Ru rubidium		Rh rhodium		Pd palladium		Ag silver		
	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	ng/m3	
AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD
<b>PM10</b>																					
<b>FTP 1A</b>																					
UC A	127.6	6.9	232.2	22.1	2.60	0.16	7.85	0.47	6.05	0.32	4.51	0.23	0.2091	0.0406	0.2047	0.0748	1.8687	0.1502	0.4051	0.0267	
Blank 1	21.3	1.1	312.0	24.1	1.78	0.17	8.82	0.46	1.28	0.13	1.54	0.09	0.1836	0.0232	0.1494	0.0391	1.6607	0.0915	0.3842	0.0547	
SS A																					
FTP 2A	73.9	3.9	302.4	15.8	2.55	0.14	6.22	0.36	7.79	0.40	4.45	0.27	0.1086	0.0438	0.1173	0.0352	1.3898	0.1593	0.3561	0.039	
Blank 2	6.0	0.4	111.3	15.4	2.06	0.16	6.88	0.36	1.06	0.13	2.63	0.18	0.1647	0.0389	0.1816	0.0598	1.4189	0.195	0.2703	0.0403	
FTP 1B																					
UC B	235.3	13.9	355.8	20.5	8.19	0.50	10.67	0.77	139.57	7.63	15.89	0.89	0.2336	0.0426	0.2377	0.0387	1.2538	0.1236	0.3934	0.0348	
Blank 3	8.5	1.7	109.2	26.9	2.60	0.31	7.48	0.40	2.89	0.51	3.07	0.25	0.387	0.0926	0.3747	0.1494	1.4823	0.2034	0.4159	0.073	
SS B																					
FTP 2B	160.1	8.6	319.2	16.1	5.43	0.29	8.41	0.48	96.22	4.97	11.87	0.65	0.1217	0.0259	0.0839	0.0255	1.108	0.1224	0.2644	0.0157	
<b>PM2.5</b>																					
FTP 1A	54.7	2.8	202.7	11.1	2.63	0.23	3.98	0.21	4.65	0.26	3.47	0.20	0.0711	0.0134	0.0452	0.0227	0.6718	0.0644	0.1679	0.0365	
UC A	110.9	5.7	179.7	10.2	2.95	0.15	3.91	0.23	5.35	0.29	5.06	0.26	0.0682	0.0073	0.0422	0.0164	0.714	0.0741	0.2239	0.0197	
Blank 1	6.8	0.4	173.4	9.9	2.17	0.13	4.48	0.26	0.89	0.08	2.96	0.15	0.078	0.0167	0.0488	0.0164	0.7672	0.0958	0.1495	0.0209	
SS A	57.7	3.0	262.4	13.6	2.30	0.12	3.89	0.25	3.94	0.22	3.63	0.20	0.0631	0.0169	0.0365	0.0167	0.6745	0.0658	0.2426	0.0292	
FTP 2A	43.7	2.4	185.0	9.9	2.49	0.13	3.92	0.36	4.40	0.27	2.36	0.12	0.0712	0.0134	0.0259	0.0035	0.5989	0.0863	0.2136	0.0222	
Blank 2	4.8	0.3	88.9	5.2	2.02	0.16	4.32	0.27	0.71	0.11	3.20	0.21	0.0845	0.0264	0.052	0.0294	0.7186	0.0979	0.1333	0.03	
FTP 1B	125.5	7.2	271.0	14.4	3.04	0.50	4.85	1.16	34.87	2.08	4.58	0.34	0.2485	0.3971	0.2227	0.3971	1.0068	0.8147	2.062	3.7123	
UC B	264.6	13.7	383.6	19.2	6.58	0.34	9.37	0.62	163.31	8.86	25.46	1.42	0.0514	0.0131	0.0353	0.0194	0.5878	0.0592	0.3212	0.0206	
Blank 3	4.6	0.3	40.8	2.6	2.03	0.11	4.07	0.36	1.18	0.10	3.77	0.22	0.0795	0.0321	0.0286	0.0065	0.722	0.102	0.1813	0.024	
SS B	44.2	2.3	173.6	10.2	2.38	0.12	3.57	0.19	7.10	0.38	1.73	0.09	0.0582	0.0133	0.0388	0.0038	0.6596	0.0813	0.2231	0.0196	
FTP 2B	49.4	2.6	108.3	5.9	3.70	0.20	3.97	0.31	25.05	1.31	4.58	0.23	0.0576	0.01	0.0352	0.0129	0.5477	0.0907	0.1697	0.027	

**DYNAMOMETER TESTS, concentrations in the chamber in vehicle tests and blank tests**

	<b>Cd</b>		<b>Sb</b>		<b>Cs</b>		<b>Ba</b>		<b>Ce</b>		<b>W</b>		<b>Pt</b>		<b>Tl</b>		<b>Pb</b>		<b>U</b>		
<b>PM10</b>	<b>cadmium</b>		<b>antimony</b>		<b>cesium</b>		<b>barium</b>		<b>cerium</b>		<b>tungsten</b>		<b>platinum</b>		<b>thallium</b>		<b>lead</b>		<b>uranium</b>		
	ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		ng/m3		
<b>TEST*</b>	AVG SD		AVG SD		AVG SD		AVG SD		AVG SD		AVG SD		AVG SD		AVG SD		AVG SD		AVG SD		
<b>FTP 1A</b>																					
<b>UC A</b>	0.3049	0.0503	1.9471	0.1366	3.16	0.18	470.1	26.8	31.10	1.95	1.015	0.0524	0.7579	0.2943	0.2614	0.0332	15.015	6.906	0.1481	0.0571	
<b>Blank 1</b>	0.3245	0.0619	0.9947	0.0714	3.49	0.24	4.9	0.6	23.25	4.47	0.6446	0.0535	0.4952	0.1768	0.2135	0.0358	10.477	3.696	0.1153	0.0389	
<b>SS A</b>																					
<b>FTP 2A</b>	3.1489	0.2377	2.2672	0.133	2.24	0.12	667.2	36.6	15.32	1.16	0.8078	0.0562	0.3301	0.0842	0.1433	0.0355	7.4313	1.548	0.0869	0.0307	
<b>Blank 2</b>	0.2703	0.0484	0.8572	0.0632	2.53	0.13	4.8	0.3	23.53	2.76	0.4687	0.0597	0.6757	0.2933	0.1647	0.0266	11.039	3.8446	0.1267	0.0385	
<b>FTP 1B</b>																					
<b>UC B</b>	0.3278	0.048	2.8764	0.1719	2.03	0.18	8367.3	460.3	34.25	2.54	2.5527	0.1517	0.8031	0.1568	0.2049	0.0305	13.521	2.4669	0.1885	0.042	
<b>Blank 3</b>	0.5353	0.0788	0.7535	0.1891	2.36	0.13	16.7	1.7	26.13	3.24	0.7247	0.1848	1.1199	0.5054	0.3417	0.1084	21.941	8.8302	0.3129	0.1327	
<b>SS B</b>																					
<b>FTP 2B</b>	0.256	0.0246	2.8246	0.1582	1.83	0.11	5982.8	311.8	9.93	1.37	1.7543	0.0972	0.1511	0.0385	0.1133	0.0217	4.3565	0.4729	0.0588	0.0089	
<b>PM2.5</b>																					
<b>FTP 1A</b>	0.197	0.0494	1.4469	0.106	1.28	0.08	402.9	21.8	8.27	0.52	0.4522	0.0343	0.1227	0.0552	0.0549	0.0101	4.8219	1.6615	0.0291	0.0259	
<b>UC A</b>	0.8503	0.1003	1.4636	0.0766	1.28	0.09	446.8	24.6	6.00	0.46	0.4511	0.0422	0.1233	0.0235	0.0617	0.0165	2.3139	0.1644	0.0162	0.0065	
<b>Blank 1</b>	0.091	0.0138	0.6339	0.041	1.46	0.09	4.7	0.7	8.87	1.16	0.2341	0.0285	0.0975	0.0782	0.0748	0.0167	1.0825	0.159	0.013	0.0033	
<b>SS A</b>																					
<b>FTP 2A</b>	0.1554	0.024	1.3822	0.0809	1.26	0.08	386.3	24.9	5.64	0.35	0.3982	0.0525	0.0809	0.0455	0.0647	0.0165	1.8095	0.2172	0.0259	0.013	
<b>Blank 2</b>	0.1463	0.0333	0.66	0.0383	1.34	0.09	6.0	0.5	7.31	0.86	0.2146	0.0884	0.0423	0.0196	0.0553	0.0043	1.2713	0.2426	0.0163	0.013	
<b>FTP 1B</b>																					
<b>UC B</b>	0.2872	0.2747	1.7586	0.1952	1.20	0.18	2298.2	133.9	7.13	0.38	0.6744	0.1056	0.2904	0.4713	0.1194	0.1357	6.4601	3.712	0.1097	0.1711	
<b>UC B</b>	0.3758	0.0269	2.9838	0.16	1.14	0.07	7215.7	393.5	5.54	0.37	2.5116	0.1564	0.0482	0.004	0.0578	0.0101	4.3841	0.3402	0.045	0.0068	
<b>Blank 3</b>	0.5439	0.0395	0.2354	0.0198	1.16	0.07	11.8	1.4	4.71	0.49	0.2004	0.0613	0.0732	0.0226	0.0763	0.0133	1.3549	0.7822	0.0127	0.0096	
<b>SS B</b>																					
<b>FTP 2B</b>	0.194	0.0338	3.5112	0.1907	1.11	0.11	394.0	20.3	5.91	0.46	0.3524	0.0608	0.097	0.0359	0.0776	0.0166	2.5024	0.2201	0.0517	0.0164	
<b>FTP 2B</b>	0.1409	0.0297	0.9448	0.0674	0.99	0.07	1592.9	84.3	5.54	0.39	0.6277	0.0352	0.0961	0.0578	0.0448	0.013	1.5085	0.3666	0.0609	0.0641	