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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Moisture effects on carbon and nitrogen emission from burning of wildland biomass" *by* L.-W. A. Chen et al.

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We appreciate the reviewer's comments. We have added several discussions regarding the measurement uncertainty in the revised manuscript. The analytical precision of filter measurements has been well established in the referred literature (Chow, 1995; Chow et al., 2004). For gases, they were established from the calibration process. In the Method section, we added–

"Least quantifiable limits (LQLs) were established with dynamic blanks through the same sampling channels but in the absence of combustion. Measurement precision is <10% for concentrations greater than 10 times the LQLs"– in Section 2, 5th paragraph.

"The detection ranges (10-s average) were 0.001–10, 0.1–3000, and 1–10000 ppmv for the TECO, Li-Cor, and Midac analyzers, respectively. The precision of gas measurements is estimated to be <5% if they are within the instrumental detection range. All our experiments met the condition"– in Section 2, 6th paragraph.

However, the analytical precision does not take into account gas or particle losses in the sampling line, in the Results and Discussion, we added–

"NH3 from the TECO 17C correlated reasonably with those of filters (r = 0.83), but the TECO 17C values were lower by an average of 21% and as much as 80%. This most possibly results from the loss of NH3 in the Teflon sampling tubing and to the pre-analyzer particle filter (e.g., Mukhtar et al., 2003). EF calculations (i.e., Table 1) were therefore based on filter measurements which deployed much shorter/larger diameter tubing from the plenum. CO2, CO, and NOx adsorption on Teflon surface are generally negligible"– in Section 3, 2nd paragraph.

"NH3 concentrations in Figure 6 (from TECO 17C) may be biased low as the averaged NH3 for these two burns are ∼10% lower than those measured on filters. They are only discussed qualitatively below"– in Section 3.3, 1st paragraph. "The burn-averaged particle volume concentration correlates well with PM2.5 mass measured on Teflon filters (r = 0.90, across all the samples) with a mass/volume slope of 1.01 +/- 0.08 g/cm3."– in Section 3.3, 3rd paragraph.

Note that the continuous ammonia measurements are only used for qualitative discussion in this paper, which has been clarified. Since the natural variability of EFs, according to replicate burns, usually exceeds the EF uncertainties estimated from the analytical precision, we decided to report the EF uncertainties from the standard deviation of replicate experiments. This is consistent with McMeeking et al (2009), who also based EFs on 2 – 3 replicates. Table 1 has been revised to show the mean +/- standard deviation. Figure 3 is added to illustrate the dependence of EFs on fuel moisture content under the context of replicate uncertainty. We found the dependence is more significant for plant leaves and duff.

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Table 1. Time-integrated combustion efficiency (*CE*) and emission factors[a] for major C and N species as well as $PM_{2.5}$ from controlled burning experiments.

Plant Species		Downed Material			Aboveground Shrub					
		Composite			Bitterbrush		Manzanita		Squaw Carpet	
Parameter\Fuel Type		Litter	Duff	Soil	Leaves	Stems	Leaves	Stems	Leaves	Stems
Moisture Level I (Dry[f])	Carbon %[b]	*50%*	*32%*	*3%*	*52%*	*48%*	*49%*	*48%*	*47%*	*50%*
	Burned %[c]	*92%*	*52%*	*9%*	*92%*	*81%*	*90%*	*98%*	*83%*	*93%*
	CE	*0.94 ± 0.01*	*0.92 ± 0.02*	*0.86 ± 0.02*	*0.93 ± 0.01*	*0.94 ± 0.00*	*0.91 ± 0.01*	*0.94 ± 0.00*	*0.92 ± 0.01*	*0.92 ± 0.00*
	CO	126.2 ± 12.7	140.6 ± 27.3	297.3 ± 48.2	112.6 ± 30.3	127.4 ± 8.8	113.2 ± 43.5	128.4 ± 6.7	144.5 ± 22.3	162.1 ± 8.9
	OC[e]	2.5 ± 0.2	9.3 ± 6.7	14.9 ± 4.4	9.1 ± 1.8	6.4 ± 2.0	21.2 ± 7.9	5.5 ± 0.6	11.3 ± 0.2	4.7 ± 0.1
	EC[e]	4.6 ± 0.3	5.7 ± 0.1	0.7 ± 0.2	15.4 ± 2.7	2.9 ± 0.3	15.9 ± 3.9	2.0 ± 0.4	8.1 ± 0.8	2.5 ± 0.5
	$PM_{2.5}$[e]	8.1 ± 0.9	18.3 ± 10.2	N.D.	27.1 ± 5.8	13.0 ± 3.9	47.5 ± 14.1	8.7 ± 0.4	25.3 ± 3.2	14.5 ± 1.1
	NO_x	5.9 ± 0.3	4.9 ± 0.9	0.9 ± 0.2	9.1 ± 2.8	9.1 ± 1.0	7.1 ± 3.0	5.4 ± 1.0	7.7 ± 1.5	10.5 ± 0.8
	NH_3[e]	1.3 ± 1.1	3.7 ± 2.4	11.5 ± 6.1	7.7 ± 2.4	3.4 ± 0.6	4.0 ± 1.6	1.9 ± 0.8	6.8 ± 1.6	5.6 ± 0.1
	NO_3^-[e]	0.04 ± 0.01	0.03 ± 0.02	N.D.	0.05 ± 0.01	0.12 ± 0.00	0.16 ± 0.04	0.12 ± 0.00	0.07 ± 0.00	0.09 ± 0.02
	NH_4^+[e]	0.05 ± 0.01	0.06 ± 0.03	N.D.	0.04 ± 0.00	0.04 ± 0.01	0.04 ± 0.00	0.03 ± 0.00	0.05 ± 0.00	0.08 ± 0.00
	OPN[e]	0.24 ± 0.19	0.44 ± 0.35	0.31 ± 0.23	0.40 ± 0.11	0.31 ± 0.12	0.47 ± 0.21	0.09 ± 0.03	0.45 ± 0.04	0.28 ± 0.01
Moisture Level II	Moisture[d]	*10%*	*10%*	*10%*	*73%*	*39%*	*40%*	*39%*	*48%*	*44%*
	Burned %[c]	*72%*	*47%*	*10%*	*88%*	*66%*	*73%*	*53%*	*69%*	*92%*
	CE	*0.79 ± 0.06*	*0.70 ± 0.07*	*0.80 ± 0.06*	*0.88 ± 0.01*	*0.82 ± 0.06*	*0.72 ± 0.03*	*0.86 ± 0.11*	*0.67 ± 0.09*	*0.86 ± 0.06*
	CO	253.2 ± 59.8	444.9 ± 68.1	431.4 ± 143.8	113.2 ± 42.4	261.3 ± 44.0	97.5 ± 76.7	107.1 ± 2.4	77.7 ± 57.7	108.1 ± 96.0
	OC[e]	99.8 ± 34.9	110.9 ± 41.5	17.5 ± 1.0	66.1 ± 9.9	66.6 ± 36.1	236.0 ± 62.4	62.8 ± 64.1	292.2 ± 115.1	92.6 ± 18.4
	EC[e]	5.2 ± 0.3	1.0 ± 0.1	1.5 ± 0.5	7.3 ± 4.0	3.7 ± 0.7	5.6 ± 1.1	2.3 ± 1.2	8.5 ± 3.2	2.6 ± 0.3
	$PM_{2.5}$[e]	160.5 ± 56.2	143.9 ± 62.2	N.D.	96.9 ± 18.3	119.3 ± 73.7	214.9 ± 84.1	94.9 ± 91.3	270.8 ± 68.4	109.6 ± 32.7
	NO_x	6.4 ± 1.5	6.7 ± 1.4	2.8 ± 0.8	9.9 ± 4.0	13.0 ± 3.1	2.2 ± 2.9	2.9 ± 1.2	4.0 ± 5.4	10.7 ± 7.9
	NH_3[e]	4.3 ± 1.7	26.7 ± 14.0	24.7 ± 6.6	10.2 ± 1.5	10.7 ± 0.9	10.0 ± 0.5	3.8 ± 0.5	11.9 ± 4.1	11.0 ± 5.4
	NO_3^-[e]	0.17 ± 0.00	0.13 ± 0.01	N.D.	0.23 ± 0.02	0.20 ± 0.02	0.08 ± 0.03	0.08 ± 0.01	0.23 ± 0.04	0.20 ± 0.01
	NH_4^+[e]	0.24 ± 0.04	0.15 ± 0.01	N.D.	0.10 ± 0.00	0.03 ± 0.02	0.31 ± 0.09	0.05 ± 0.06	0.28 ± 0.11	0.06 ± 0.01
	OPN[e]	1.62 ± 0.59	3.57 ± 1.50	0.99 ± 0.26	2.03 ± 0.05	1.39 ± 0.68	4.4 ± 1.42	1.07 ± 1.33	7.70 ± 3.28	2.17 ± 0.46
Moisture Level III	Moisture[d]	*20%*	*20%*	*20%*	*84%*	*57%*	*60%*	*52%*	*66%*	*57%*
	Burned %[c]	*80%*	*45%*	*9%*	*86%*	*78%*	*68%*	*92%*	*65%*	*90%*
	CE	*0.74 ± 0.10*	*0.69 ± 0.07*	*0.82 ± 0.01*	*0.51 ± 0.07*	*0.84 ± 0.04*	*0.62 ± 0.09*	*0.87 ± 0.00*	*0.72 ± 0.01*	*0.88 ± 0.08*
	CO	313.6 ± 105.8	407.6 ± 29.2	357.7 ± 15.9	215.6 ± 31.1	216.8 ± 60.4	134.2 ± 43.5	188.5 ± 25.1	142.6 ± 22.3	133.1 ± 102.6
	OC[e]	116.6 ± 48.8	131.1 ± 59.2	22.1 ± 0.8	393.6 ± 54.1	67.8 ± 11.1	315.3 ± 111.1	43.1 ± 5.8	210.4 ± 20.2	61.5 ± 39.7
	EC[e]	7.6 ± 4.9	1.1 ± 0.2	2.3 ± 0.9	5.3 ± 0.5	3.6 ± 0.1	7.7 ± 1.3	2.6 ± 1.0	4.8 ± 0.0	2.7 ± 0.7
	$PM_{2.5}$[e]	179.9 ± 54.7	208.9 ± 56.2	N.D.	768.7 ± 43.2	99.5 ± 4.4	493.8 ± 231.9	61.5 ± 3.8	387.2 ± 31.1	129.1 ± 43.5
	NO_x	8.4 ± 2.5	3.8 ± 0.2	5.4 ± 0.1	9.6 ± 2.0	7.5 ± 0.5	2.7 ± 2.0	4.7 ± 0.5	6.4 ± 2.2	9.1 ± 2.3
	NH_3[e]	5.3 ± 0.4	17.7 ± 5.9	24.5 ± 18.0	19.1 ± 1.4	10.9 ± 1.8	10.1 ± 0.4	3.8 ± 0.0	9.5 ± 0.8	9.7 ± 4.9
	NO_3^-[e]	0.20 ± 0.05	0.09 ± 0.03	N.D.	0.28 ± 0.11	0.18 ± 0.02	0.12 ± 0.00	0.11 ± 0.01	0.14 ± 0.03	0.13 ± 0.08
	NH_4^+[e]	0.30 ± 0.11	0.15 ± 0.06	N.D.	0.32 ± 0.11	0.06 ± 0.01	0.42 ± 0.14	0.07 ± 0.01	0.18 ± 0.00	0.05 ± 0.03
	OPN[e]	1.59 ± 0.56	3.36 ± 1.40	0.60 ± 0.07	11.83 ± 0.53	1.59 ± 0.39	4.32 ± 1.52	0.66 ± 0.04	4.43 ± 0.36	1.33 ± 0.76

Fig. 1. Revised Table 1.

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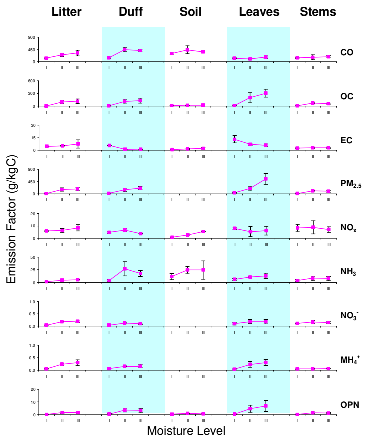

Figure 3. Emission factors, by fuel type, as a function of fuel moisture level, based on data presented in Table 1 (all the leaf and stem data have been combined).

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Fig. 2. New Figure 3.

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