

CHARACTERIZATION OF THE MAINSTREAM AND THE SIDESTREAM CIGARETTE SMOKE SIMULTANEOUSLY GENERATED USING AUTOMATED CIGARETTE SMOKE EXPOSURE SYSTEM

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ABSTRACT

Mainstream (MS) and sidestream (SS) smoke of 3R4F reference cigarettes was simultaneously generated using a modified JB-2070 smoking machine and directed to the two different exposure carousels. Three target exposure concentrations within the range of commonly used in smoke toxicity studies were selected per WTPM (wet total particulate matter): MS smoke (500, 250, and 60 µg/L); SS smoke (130, 95, and 55 µg/L). The exposure duration was 1 hr for all exposure runs. CO (carbon monoxide), WTPM, nicotine, aldehydes (formaldehyde, acetaldehyde, acrolein, propionaldehyde, and crotonaldehyde), butt lengths, particle size, and environmental parameters (temperature and relative humidity) at the animal exposure nose-ports were measured. Exposure was controlled by Battelle Exposure Data Acquisition and Control (BEDAC) automated system.

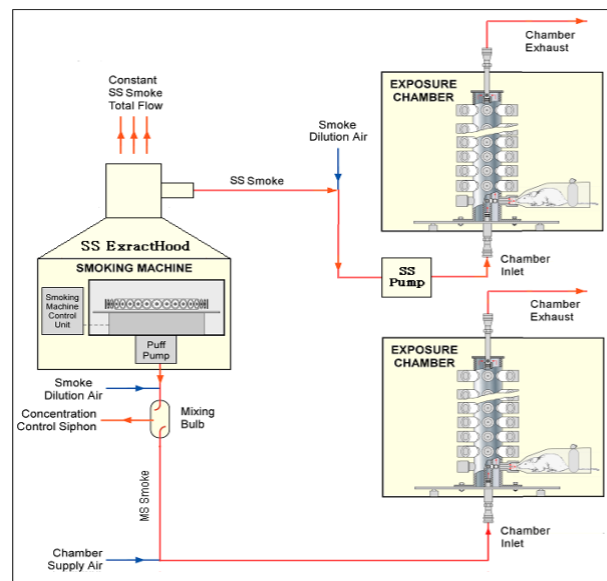
METHODS

Cigarette smoke was generated using a modified JB-2070 smoking machine which was redesigned for continuous simultaneous generation of mainstream smoke and sidestream smoke directed to the two different exposure carousels (Figure 1). Each carousel consists of five stackable tiers with 16 Cannon-style nose-only exposure ports per tier (providing up to 80 ports for animal exposure and test atmosphere sampling). The study was conducted using three dose levels for the MS Smoke (500, 250, and 60 µg/L) and three dose levels for the SS smoke (130, 95, and 55 µg/L).

Three 1-hour Tests (1 test per dose for the both mainstream and sidestream smoke, conducted simultaneously) were conducted each day during a three day test period.

Smoke aerosol concentration of the MS smoke was monitored with the real-time aerosol monitor (RAM; Casella Microdust, Pro; Amherst, NH). Smoke aerosol concentration of the SS smoke was monitored with the Scanning Mobility Particle Sizer (SMPS; TSI Inc; St Paul, MI). WTPM was assessed by gravimetric analysis of filter samples collected throughout the entire duration of the exposure.

Figure 1. General Schematics of the Exposure



Spatial homogeneity of smoke was determined by obtaining duplicate filters from the top, middle, and low tiers. Spatial homogeneity among and between the tiers was defined as no greater than 7% of relative standard deviation (%RSD). Satisfactory spatial homogeneity among the tiers (7% RSD) was also confirmed by nose-port velocity measurements. CO concentration was monitored during each smoke exposure using CO-analyzer (California Analytical Instruments Inc.; Orange, CA). The particle size of the MS smoke was determined using a Mercer-style cascade impactor. Particle size of the SS smoke was measured using a SMPS. Smoke nicotine (filters and sorbent tubes) was quantified using gas chromatography (GC) with FID detection. Aldehyde samples were collected by bubblers and analyzed using HPLC with UV detection. Each exposure carousel also includes monitors for temperature, relative humidity, and air flows. All data are automatically recorded by the BEDAC System. BEDAC also controls the timing of exposures and filter samples.

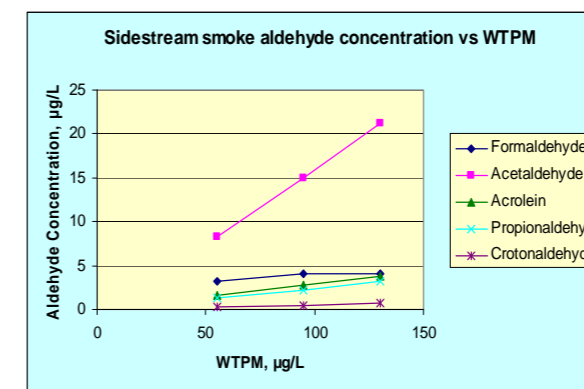
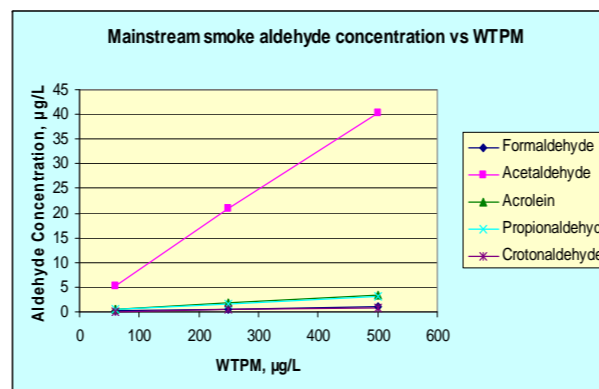
RESULTS

Mainstream Data Summary (WTPM, CO, nicotine, particle size)

	WTPM (µg/L)	Avg CO (ppm)	Butt Length (mm)	Nicotine Conc (µg/L)	MMAD (µm)	GSD	CO to WTPM	CO to Nicotine	Nicotine to WTPM x 1000
Mean:	486.1	495.4	40.4	33.6	0.61	1.36	1.020	14.7	69.3
St Dev:	15.9	7.8	NA	0.7	0.03	0.05	0.029	0.1	1.8
% RSD:	3.3%	1.6%	NA	2.1%	4.9%	3.7%	2.8%	0.7%	2.6%
Mean:	248.8	259.8	40.0	17.2	0.62	1.30	1.045	15.1	69.2
St Dev:	8.4	1.6	NA	0.4	0.01	0.01	0.037	0.3	1.4
% RSD:	3.4%	0.6%	NA	2.3%	1.6%	0.8%	3.5%	2.0%	2.0%
Mean:	61.4	63.9	40.1	4.8	0.61	1.32	1.044	13.1	76.8
St Dev:	4.4	1.7	NA	0.2	0.01	0.03	0.077	0.1	3.0
% RSD:	7.2%	2.7%	NA	4.2%	1.6%	2.3%	7.4%	0.8%	3.9%

Sidestream Data Summary (WTPM, CO, nicotine, particle size)

	WTPM (µg/L)	Avg CO (ppm)	Butt Length (mm)	Nicotine Conc (µg/L)	CMAD (nm)	GSD	CO to WTPM	CO to Nicotine	Nicotine to WTPM x 1000
Mean:	132.4	463.8	40.4	20.2	133.7	1.58	3.521	23.0	152.9
St Dev:	12.9	6.1	NA	1.4	2.26	0.01	0.289	1.1	5.7
% RSD:	9.7%	1.3%	NA	6.9%	1.7%	0.6%	8.2%	4.8%	3.7%
Mean:	94.3	328.0	40.0	20.0	124.2	1.60	3.504	16.4	213.2
St Dev:	8.7	12.2	NA	1.1	0.60	0.00	0.461	1.5	8.1
% RSD:	9.2%	3.7%	NA	5.5%	0.5%	0.0%	13.2%	9.1%	3.8%
Mean:	53.9	178.1	40.1	15.9	112.5	1.64	3.306	11.2	294.6
St Dev:	4.9	17.5	NA	1.1	2.83	0.01	0.283	1.0	6.6
% RSD:	9.1%	9.8%	NA	6.9%	2.5%	0.6%	8.6%	8.9%	2.2%



CONCLUSIONS

- WTPM, CO, and nicotine data and their ratios demonstrated reproducible stability of the smoke generation and delivery system for both MS and SS smoke, with RSD <10%.
- Nicotine concentration of MS smoke overall linearly increased with the increase in WTPM. Most of the aldehyde concentrations of MS smoke also linearly increased with the increasing WTPM exposure concentrations, except for formaldehyde (its ratio to WTPM increased with WTPM decrease).
- SS smoke data showed higher nicotine and aldehyde content per WTPM than MS smoke. Nicotine/WTPM ratio of SS smoke increased with increasing WTPM. Similarly to MS smoke, most of the aldehyde concentrations of SS smoke linearly increased with the increase of the target WTPM exposure concentrations (except for formaldehyde/WTPM ratio increase with WTPM decrease). MS smoke particle size was stable for all three exposure concentrations (MMAD varied from 0.61 to 0.62 micron), whereas SS smoke particle size was significantly smaller than the MS smoke, tended to decrease with decreasing WTPM concentration (from 133.7 to 112.5 nm CMAD). This may explain the increasing of nicotine to WTPM ratio of the SS smoke with decreasing WTPM concentration (semivolatile nicotine stays with particle while high volatile compounds may evaporate).
- Difficulties on accurate quantitation of formaldehyde are well known (Borgerding and Klus, *Experimental and Toxicologic Pathology*, 57, 2005 pp. 43-73) and this study confirms this observation.
- In summary, the current exposure system allows stable and automated generation and monitoring of simultaneous exposure of MS and SS smoke up to 72 animals per each smoke type.

Acknowledgement

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