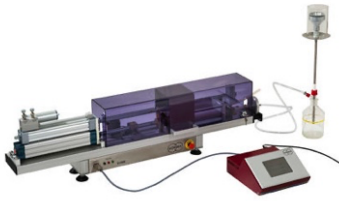
Supplementary Figure 1. Study Products.

Product	Manufacturer	Image
PM1 shisha smoking machine (conventional waterpipe smoking machine)	Körber Technologies Instruments GmbH	
Wood-derived charcoal	Three Kings	
Coconut-derived charcoal	BLACKCOCO's GmbH	
Lotus heat management device	Kaloud	
"Two Apples" shisha tobacco	Al Fakher	
OOKA electronic waterpipe and pods containing "Two Apples" shisha tobacco	Advanced Inhalation Rituals	 
IQOS 3.0 (ILUMA) HTP and TEREA Teak sticks	Philip Morris International	 
3R4F reference cigarette	University of Kentucky	 

Supplementary Table 1. Analytical Methods. [a]Formaldehyde, acetaldehyde, acetone, acrolein, propionaldehyde, crotonaldehyde, 2-butanone and butyraldehyde. [b]NNN, NNK, NAT and NAB. [c]1-aminonapthalene and 2-aminonapthalene. [d]1,3-butadiene, isoprene, acrylonitrile, benzene, toluene. [e]phenol, *m*-cresol, *p*-cresol, *o*-cresol, catechol (1,2-dihydroxybenzene), resorcinol (1,3-dihydroxybenzene), hydroquinone.

Analyte	Sample Preparation	Analytical Method	Method Reference
TCM	Collected on Cambridge filter pad	Analytical scale	ISO/TS 22487:2019-05
CO	Collected in gas collection bag	NDIR	ISO/TS 22491: 2019-05
Nicotine	Collected on Cambridge filter pad	GC-FID	ISO 20714:2019-08
Propylene glycol	Collected on Cambridge filter pad	GC-FID	ISO 20714:2019-08
Glycerol	Collected on Cambridge filter pad	GC-FID	ISO 20714:2019-08
Water	Collected on Cambridge filter pad	Colorimetric titration	Karl Fischer method (ISO 10362-2:2013)
Carbonyls[a]	Impinger with DNPH solution	HPLC-UV	ISO 21160:2018-11
TSNAs[b]	Collected on Cambridge filter pad	LC-MS/MS	Smoking according to ISO 22486/2019-05
B[a]P	Collected on Cambridge filter pad	GC-MS	Smoking according to ISO 22486/2019-05
Ammonia	Impinger with 0.1N sulfuric acid plus Cambridge filter pad	Photometric detection	Based on Health Canada Test Method T-101
Aminonaphthalenes[c]	Impinger with 5% hydrochloric acid	GC-MS	Based on Health Canada Test Method T-102
4-ABP	Impinger with 5% hydrochloric acid	GC-MS	Based on Health Canada Test Method T-102
VOCs[d]	Dry ice/isopropanol cooling trap (impinger) with methanol	GC-MS	Based on Health Canada Test Method T-116
Phenolics[e]	Collected on Cambridge filter pad	HPLC-FLD	Based on Health Canada Test Method T-114

Abbreviations: TCM, total collected matter; CO, carbon monoxide; TSNAs, tobacco-specific nitrosamines; NNN, *N*'-nitrosonornicotine; NNK, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone; NAT, *N'*-nitrosoanatabine; NAB, *N*'-nitrosoanabasine; B[a]P, benzo[a]pyrene; 4-ABP, 4-aminobiphenyl; VOCs, volatile organic compounds; NDIR, non-dispersive infrared; ISO, International Organization for Standardization; TS, Technical Specification; LC-MS/MS, liquid chromatography-tandem mass spectrometry; GC-MS, gas chromatography-mass spectrometry; NDIR, nondispersive infrared; GC-FID, gas chromatography flame ionization detector; HPLC-UV, high-performance liquid chromatography-ultraviolet; HPLC-FLD, high-performance liquid chromatography-fluorescence detector.

Supplementary Table 2. Concentrations of Emissions Analytes from Conventional and Electronic Waterpipes, Reference Cigarettes, and a Heated Tobacco Product. Data are presented as means ± SD from 3 replicates. Data were calculated from those shown in Table 2 using total puff volumes of 92.75 l for the conventional and electronic waterpipe products (175 puffs of 530 ml volume), 0.55 l for IQOS 3.0 (11 puffs of 55 ml volume), and 0.572 - 0.605 l for the 3R4F reference cigarette (based on an average number of 55 ml volume puffs, depending on the analyte). [a]Data taken from Eldridge *et al* [19]. [b]Based on 2 replicates. [c]Average yield when HMD used with 0%, 50% and 100% ventilation settings.

	Conventional Waterpipe Heated with Wood-Derived Charcoal	Conventional Waterpipe Heated with Coconut-Derived Charcoal	Conventional Waterpipe Heated with Coconut-Derived Charcoal within a HMD	OOKA Electronic Waterpipe	IQOS 3.0 (ILUMA) HTP	3R4F Reference Cigarette[a]
Analyte	**Yield**	**Yield**	**Yield**	**Yield**	**Yield**	**Yield**
TCM (mg/ml puff volume)	56.32 ± 1.67	48.43 ± 4.19	41.42 ± 5.49	35.12 ± 3.82	NA	NA
TPM (mg/ml puff volume)	NA	NA	NA	ND	61.4 ± 1.0	77.1 ± 4.2
Water (mg/ml puff volume)	31.66 ± 1.33	28.45 ± 2.32	27.06 ± 3.40	22.42 ± 1.54	23.4 ± 0.2	27.8 ± 1.2
Nicotine (mg/ml puff volume)	0.06 ± 0.00	0.09 ± 0.01	0.05 ± 0.01	0.05 ± 0.00	2.0 ± 0.1	3.4 ± 0.1
NFDPM (mg/ml puff volume)	NA	NA	NA	NA	36.0 ± 0.9	46.0 ± 1.2
Glycerol (mg/ml puff volume)	15.38 ± 0.34	11.95 ± 0.51	8.09 ± 1.77	8.48 ± 0.34	8.6 ± 0.5	ND
Propylene Glycol mg/ml puff volume)	0.58 ± 0.34	11.95 ± 0.51	8.09 ± 1.77	8.48 ± 0.34	0.0 ± 0.0	ND
CO (μg/ml puff volume)	3.82 ± 0.24	2.42 ± 0.33	0.8 ± 0.51[c]	0.0 ± 0.0	0.4 ± 0.0	54.5 ± 1.7
Benzo[a]pyrene (pg/ml puff volume)	0.73 ± 0.30	0.31 ± 0.03	0.08 ± 0.00	0.0 ± 0.0	0.0 ± 0.0	23.1 ± 1.2
Formaldehyde (ng/ml puff volume)	8.98 ± 1.35	9.32 ± 0.52	6.35 ± 0.74	1.68 ± 0.32	13.9 ± 1.4	123.8 ± 9.9
Acetaldehyde (ng/ml puff volume)	13.75 ± 1.68	10.55 ± 0.77	8.51 ± 1.97	3.26 ± 0.23	293.6 ± 41.0	2118.4 ± 66.9
Acetone (ng/ml puff volume)	5.14 ± 0.28	2.06 ± 1.64	2.39 ± 0.51	0.10 ± 0.17	40.3 ± 7.6	988.0 ± 56.6
Acrolein (ng/ml puff volume)	3.97 ± 0.70	1.79 ± 1.16	3.76 ± 1.39	0.15 ± 0.17	13.9 ± 1.9	214.2 ± 14.6

Propionaldehyde (ng/ml puff volume)	2.02 ± 0.29	1.56 ± 0.14	0.68 ± 0.09	0.0 ± 0.0	17.3 ± 2.4	222.5 ± 10.3
Crotonaldehyde (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.51 ± 0.41	0.0 ± 0.0	0.0 ± 0.0	79.6 ± 6.2
2-Butanone (ng/ml puff volume)	0.94 ± 0.22	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	272.2 ± 13.7
Butyraldehyde (ng/ml puff volume)	1.16 ± 1.01	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	37.7 ± 1.9	148.9 ± 1.8
NNN (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	534.5 ± 35.3
NAT (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	32.7 ± 1.8	554.0 ± 39.3
NAB (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	63.5 ± 5.1
NNK (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	531.0 ± 47.3
1,3-Butadiene (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	156.6 ± 44.6
Isoprene (ng/ml puff volume)	0.053 ± 0.092	0.084 ± 0.146	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	1802.8 ± 131.5
Acrylonitrile (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	58.3 ± 2.6
Benzene (ng/ml puff volume)	5.833 ± 0.516	2.770 ± 0.106	2.657 ± 0.676	0.0 ± 0.0	0.0 ± 0.0	171.6 ± 9.7
Toluene (ng/ml puff volume)	1.877 ± 0.267	1.203 ± 0.505	0.444 ± 0.223	0.0 ± 0.0	0.0 ± 0.0	283.7 ± 14.5
1-Aminonaphthalene (ng/ml puff volume)	0.05 ± 0.06	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	38.9 ± 2.5
2-Aminonaphthalene (ng/ml puff volume)	0.04 ± 0.04	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	22.8 ± 0.8
3-Aminobiphenyl (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	7.6 ± 0.8
4-Aminobiphenyl (ng/ml puff volume)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	4.6 ± 0.2
Ammonia (ng/ml puff volume)	0.830 ± 0.173	1.19 ± 0.28	0.95 ± 0.14	0.0 ± 0.0	0.0 ± 0.0	51.6 ± 1.6
Phenol (ng/ml puff volume))	1.185 ± 0.034[b]	1.057 ± 0.064	0.81 ± 0.19	0.0 ± 0.0	0.6 ± 0.1	24.3 ± 1.0
m-, p-Cresol (ng/ml puff volume)	0.0 ± 0.0[b]	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	22.0 ± 1.5
o-Cresol (ng/ml puff volume)	0.0 ± 0.0[b]	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	7.8 ± 0.3
Catechol (ng/ml puff volume)	6.378 ± 0.702[b]	6.640 ± 0.230	5.24 ± 0.66	1.742 ± 0.161	10.0 ± 0.5	161.5 ± 8.9

Resorcinol (ng/ml puff volume)	0.0 ± 0.0[b]	0.0 ± 0.0	0.0 ± 0.0	0.039 ± 0.005	0.0 ± 0.0	3.7 ± 0.6
Hydroquinone (ng/ml puff volume)	4.341 ± 0.600[b]	2.999 ± 0.230	4.04 ± 0.50	1.242 ± 0.141	8.7 ± 0.3	143.3 ± 8.1

Abbreviations: SD, standard deviation; HTP, heated tobacco product; TCM, total collected matter; TPM, total particulate matter; NFDPM, nicotine-free dry particulate matter; CO, carbon monoxide; NNN, *N*'-nitrosonornicotine; NAT, *N*'-nitrosoanatabine; NAB, *N*'-nitrosoanabasine ; NNK, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone; ND, not determined; NA, not applicable; HMD, heat management device.