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Smoke by any other name: heat-not-burn tobacco cigarettes

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Introduction: The tobacco industry's most recent response to the documented harms of cigarette smoking was to launch new, "heat-not-burn" (HNB) tobacco cigarettes.[1] Philip Morris International (PMI) created IQOS® (I-Quit-Ordinary-Smoking): disposable tobacco sticks soaked in propylene glycol, which are inserted in a holder in the HNB cigarette. The tobacco is heated with an electric blade at 350°C (662°F). PMI markets them as a "revolutionary technology that heats tobacco without burning it, giving you the true taste of tobacco, with no smoke, no ash and less smell." [2] In many countries, laws that protect people from passive smoke only apply to 'smoked' tobacco products. PMI claims that IQOS® releases no 'smoke' because the tobacco does not 'combust' and that the tobacco leaves are only heated, not burned. But there can be smoke without fire. The harmful components of tobacco cigarette smoke are products of incomplete combustion (pyrolysis), and the degradation of tobacco cigarettes through heat (thermogenic degradation). Complete combustion occurs at high temperature [>1300°C; 2372°F], higher than the heat generated by smoking a tobacco cigarette [<800°C; <1472°F]. Typical markers of pyrolysis and thermogenic degradation of tobacco cigarette are

acetaldehyde, an irritant carcinogenic volatile organic compound, benzo[a]pyrene, a carcinogenic polycyclic aromatic hydrocarbon, and carbon monoxide.

Pilot programs for IQOS® began in 2014 in Japan, and in 2015 in Switzerland and Italy. An internet survey in Japan published in 2015 suggested younger people (15 to 39 years old) were more likely to use IQOS®, as were former smoker and current smokers.[3] Since 2016, 19 countries have allowed the sale of IQOS® cigarettes. In June 2016, data from PMI showed IQOS® had captured 2.2% of the cigarette market in Japan.[4] IQOS® are not yet sold in the US, but, in December 2016, PMI submitted a Modified Risk Tobacco Product application to the Food and Drug Administration (FDA). If successful, PMI will be less restricted in its marketing for the IQOS® than for conventional tobacco cigarettes. Smokers and non-smokers need accurate information about toxic compounds released in IQOS® smoke. This information should come from sources independent of the tobacco industry, but the only analyses we found were from PMI and PMI competitors.[1,5]

Methods: We compared the contents of IQOS® smoke with those of conventional cigarettes. We used a smoking device designed and tested in our facility to capture the mainstream aerosol, and developed to meet standards for common cigarettes and e-cigarettes.[6] We followed the ISO standards for puff volume (35 mL) at 2 puffs per minute, based on observation of IQOS® smokers, who took an average of 14 puffs over 5-6 minutes. We analyzed volatile organic compounds and nicotine by gas chromatography coupled to a flame ionization detector, and polycyclic aromatic hydrocarbons using high-performance liquid chromatography coupled to a fluorescence detector, as previously described.[6] We did not analyze polycyclic aromatic hydrocarbons generated by conventional cigarettes and present average values in 35 best-selling cigarettes brands in the US, as reported by Vu, et al.[7] We monitored the temperature near the heater blade inside the IQOS® holder and the core of the conventional cigarette, at a sampling rate of 3Hz.

Results: Volatile organic compounds, polycyclic aromatic hydrocarbons, and carbon monoxide were present in IQOS® smoke (Table). The temperature of the IQOS® was lower (330°C; 626°F) than the conventional cigarette (684°C, 1263°F).[7] IQOS® smoke had 84% of the nicotine found in conventional cigarettes smoke.

Discussion: The smoke IQOS® releases contains elements from pyrolysis and thermogenic degradation. These are the same harmful constituents of conventional tobacco cigarette smoke. PMI invited international experts to describe the IQOS® aerosol; one claims that "less than 2% of the weight of the aerosol components derive from the pyrolysis of tobacco product, which would not be sufficient to characterize the aerosol as 'smoke'".[8] In contrast, our analyses show that advertising slogans like "heat-not-burn" are no substitute for science. Dancing around the definition of smoke to avoid indoor-smoking bans is unethical. Principle 1 for implementing Article 8 of the WHO convention on tobacco control highlights that we should reject ideas that there is a threshold value for toxicity from second-hand smoke.[9] Independent studies should further evaluate the health effects of the IQOS®. In the meantime, "heated" tobacco products like IQOS® should fall under the same indoor-smoking bans as for conventional tobacco cigarettes.

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Table: Concentrations of 8 volatile organic compounds, 16 polycyclic aromatic hydrocarbons, 3 inorganic compounds and nicotine in mainstream aerosol and temperature of the heat-not-burn (HNB) IQOS® cigarette[a] and conventional cigarettes (CC)[b]

	HNB cigarette		Conventional cigarette (CC)		Proportion of the chemical in HNB/CC (%)
Analysed compounds	**Amount (SD)**	**n[c]**	**Amount (SD)**	**n[c]**	
Volatile organic compounds (µg/cig)[d]					
Acetaldehyde	133 (35)	5	610	1	22
Acetone	12.0 (12.9)	5	95.5 (13.5)	2	13
Acroleine	0.9 (0.6)	2	1.1	1	82
Benzaldehyde	1.2 (1.4)	5	2.4 (2.6)	2	50
Crotonaldehyde	0.7 (0.9)	5	17.4	1	4
Formaldehyde	3.2 (2.7)	5	4.3 (0.4)	2	74
Isovaleraldehyde	3.5 (3.1)	5	8.5 (10.8)	2	41
Propionaldehyde	7.8 (4.3)	5	29.6 (36.6)	2	26
Polycyclic Aromatic Hydrocarbons (ng/cig)[e,f]					
Naphtahlene	1.6 (0.5)	4	1105 (269)	7	0.1
Acenaphthylene	1.9 (0.6)	4	235 (39)	7	0.8
Acenaphthene	145 (54)	4	49 (9)	7	295
Fluorene	1.5 (0.6)	4	371 (56)	7	0.4
Anthracene	0.3 (0.1)	4	130 (18)	7	0.2
Phenanthrene	2.0 (0.2)	4	292 (44)	7	0.7
Fluoranthene	7.3 (1.1)	4	123 (18)	7	6
Pyrene	6.4 (1.1)	4	89 (15)	7	7
Benz[a]anthracene	1.8 (0.4)	4	33 (4.2)	7	6
Chrysene	1.5 (0.3)	4	48 (6.2)	7	3
Benzo[b]fluoranthene	0.5 (0.2)	4	24 (2.9)	7	2
Benzo[k]fluoranthene	0.4 (0.2)	4	4.3 (2.8)	7	9
Benzo[a]pyrene	0.8 (0.1)	4	20 (2.9)	7	4
Indeno[1,2,3-cd]pyrene	n.d.	4	n.a.		-
Benzo[ghi]perylene	n.d.	4	n.a.		-
Dibenzo[a,h]anthracene	n.d.	4	n.a.		-
Inorganics (ppm in the mainstream *smoke)[g]*					
CO_2	3057 (532)	5	>9000	3	-
CO	328 (76)	5	>2000	3	-
NO	5.5 (1.5)	5	89.4 (71.6)	3	6
Other measures					
Nicotine (µg/cig)[d]	301 (213)	4	361	1	84

	HNB cigarette		Conventional cigarette (CC)		Proportion of the chemical in
Analysed compounds	**Amount (SD)**	**n[c]**	**Amount (SD)**	**n[c]**	**HNB/CC (%)**
Temperature (°C)[h]	330 (10)	2	684 (197)	1	-
Puff total count[a]	12.6 (2.4)	32	13.3 (3.1)	6	-

cig. = cigarette; n.a. = not analyzed; n.d. = not detected; ppm = parts per million; SD = standard deviation.

[a] We bought the IQOS® Holder, IQOS® Pocket Charger, Marlboro HeatSticks (regular) and Heets in Lausanne, Switzerland (Philipp Morris S.A., Neuchâtel, Switzerland).

[b] Lucky Strike Blue Lights were our conventional cigarette.

[c] Number of replications for each assay.

[d] We applied the methods described previously in Varlet et al. 2016 to analyse volatile organic compounds and nicotine.

[e] We sorted polycyclic aromatic hydrocarbons by molecular weight, and then by boiling point. Polycyclic aromatic hydrocarbons from the smoke generated by the IQOS® cigarette were trapped in one glass filter (Whatman 37 mm Ø GF/B) mounted in line with an XAD2 cartridge. For each sampling, 10 IQOS® cigarettes were smoked. Each sampling support was desorbed in 10 mL of acetonitrile and sonicated for 1h. The eluate was evaporated in a vacuum concentrator (Speed Vac SC-200, Thermo, set with 30 mbar and 1000 rpm) until the residue was almost dry, to prevent evaporation of the most volatile polycyclic aromatic hydrocarbons. The residue was filtered with polytetrafluoroethylene (PTFE) membrane (Acrodisc CR 13 mm, 0.45µm) before it was analyzed with a high-performance liquid chromatography (HPLC) device (Ultimate 3000, Thermo) equipped with a fluorescence detector (FLD-3000RS), ultraviolet detector (VWD-3000), and a separation column Nucleodur EC 150×3 mm C18 3µm (Macherey-Nagel, Germany) under isocratic conditions (1.2 $mL.min^{-1}$). We injected 2 µl in the HPLC chain; (Methanol/Water-70/30)/Acetonitrile was the eluent solvent at an initial ratio of 100%/0% (4 min) and a linear gradient up to 100% acetonitrile (12 min).

[f] We present values reported from Vu, et al. 2015 for the ISO smoking regimen, and for an average of 35 top-selling U.S. cigarette brands.

[g] CO_2 was measured with a TESTO 535 (Testo, Mönchaltorf, Switzerland) and CO and NO were measured with a Pac® 7000 that detected CO (Draeger, Liebefeld/Bern, Switzerland). The apparatus measured the smoke when it was released from the syringe-pump.

[h] The temperature of the heater blade inside the IQOS® holder and the inside core of the conventional cigarette were monitored at a sampling rate of 3Hz with a type k thermocouple.