

Chemical Characterisation of Aerosol Emissions from a Prototype Heated Tobacco Product

Georgiana Cava¹, Lee Wadsworth¹, Joseph Thompson¹, Jutta Pani², Ole Dethloff² & Grant O'Connell¹

¹ Imperial Brands plc, 121 Winterstoke Road, Bristol, BS3 2LL, UK
² Reemtsma Cigarettenfabriken GmbH, Albert Einstein Ring 7, 22761, Hamburg, Germany



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1. Introduction

- Heated tobacco products generate a nicotine-containing aerosol with a tobacco taste through the heating of tobacco by an electrical device. As the tobacco is heated and not burned, the aerosol generated is expected to contain substantially lower levels of the toxicants found in the smoke produced when tobacco is burned.
- A review of the scientific literature by Public Health England recently concluded that heated tobacco products may be considerably less harmful than tobacco cigarettes but more harmful than e-vapour products [1].
- In this study, an analysis of the aerosol chemistry from a prototype heated tobacco product (PHTP; **Figure 1**) with a tobacco variant consumable was conducted. The PHTP was operated at the "high" temperature setting (c. 350°C). Levels of "tar", nicotine, carbon monoxide and a further 41 toxicants of notable public health interest were measured and compared to 3R4F cigarette smoke. The toxicants assessed included those proposed by the World Health Organization Study Group on Tobacco Product Regulation (TobReg) [2] and the US Food and Drug Administration (FDA) [3].

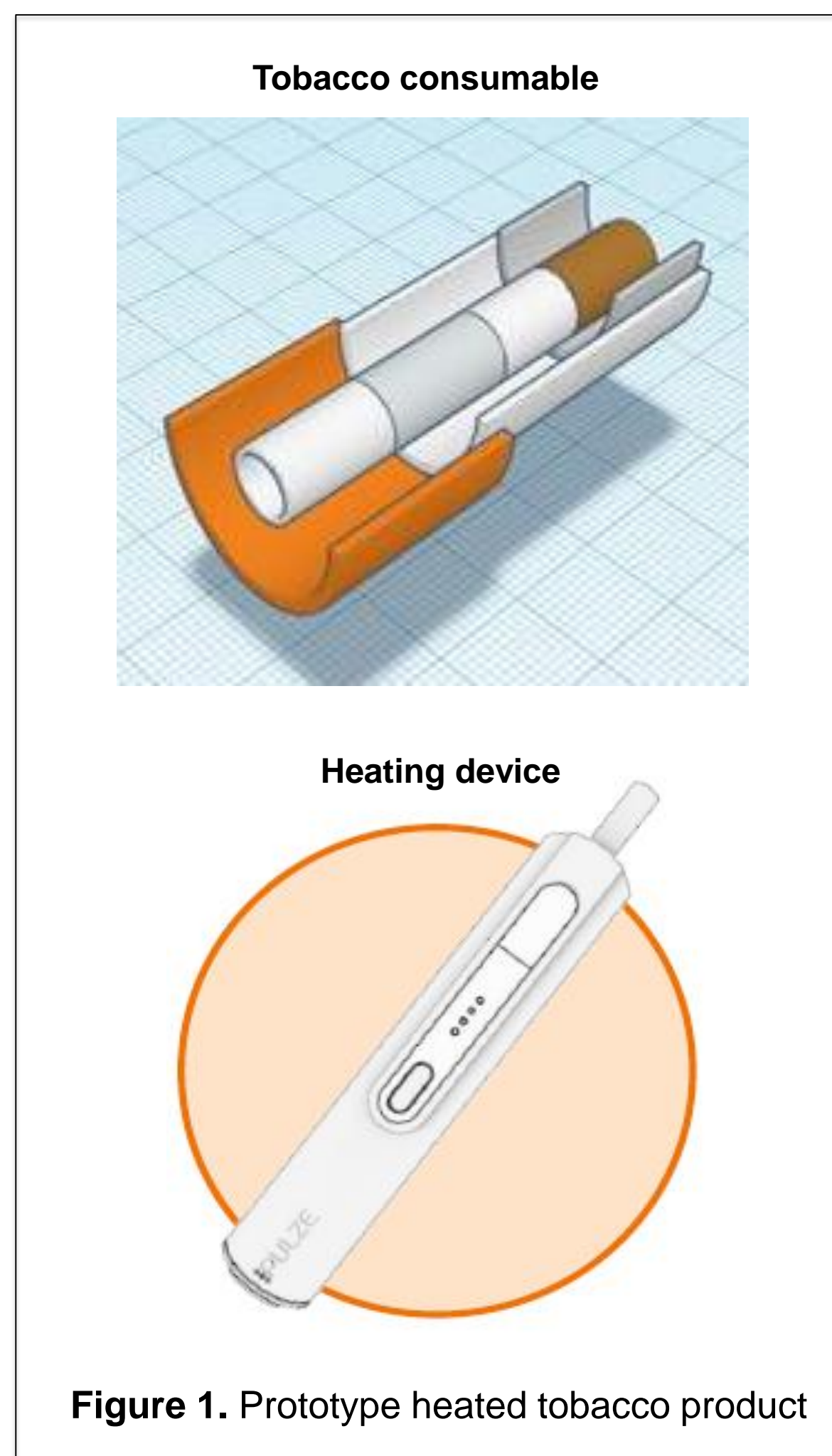


Figure 1. Prototype heated tobacco product

2. Analytical Methods

- Due to the low concentrations of toxicants and other analytes in the PHTP aerosol, the ISO Intense aerosol-generation method (puff volume, 55 mL; puff duration, 2s; puff interval, 30s; bell-shaped puff profile; product ventilation holes blocked) was used. Three replicates were measured for the PHTP and 3R4F; all values are reported as mean of 6 puffs (PHTP) and 10 puffs (3R4F) across replicates. All analyses were conducted by Imperial Brand's accredited laboratory. The methods used by the analysis laboratory are summarized in **Table 1**.

Table 1. Summary of analytical methods used for characterisation of PHTP aerosol emissions.

Analyte	Method of capture	Analysis method	Instrument
Nicotine, propylene glycol, glycerol, water	Pad	Pads are extracted with propanol	GC FID (for nicotine, propylene glycol & glycerol) / TCD (for water)
Carbonyls: Formaldehyde, Acetaldehyde, Acetone, Acrolein, Propionaldehyde, Ethylmethyl ketone, Crotonaldehyde, Butyraldehyde	Impinger	The carbonyls are trapped in a chilled acidified solution of DNPH and neutralized with pyridine	HPLC UV
Phenolics: Hydroquinone, Resorcinol, Catechol, Phenol, m-Cresol, p-Cresol, o-Cresol	Pad	The pads are extracted with a mixture of 1% acetic acid and 2.5% methanol	HPLC FLD
Volatiles: Styrene	Tedlar Bag	Vapour phase is trapped in a gas bag and directly injected	GC-MS
Ammonia	Electrostatic precipitation / impinger	Ammonia is trapped in acidic solution and extracted with salicylate	CFA
Volatiles: 1,3-Butadiene, HCN, Methanol, Ethylene Oxide, Furan, Isoprene, Propylene Oxide, Acetonitrile, Acrylonitrile, Vinyl Acetate, Methane, nitro-, Benzene, Propane, 2-nitro, Toluene, Ethyl benzene	Tedlar Bag	Vapour phase is trapped in a gas bag and directly injected	GC-MS
Metals: Arsenic, Beryllium, Cadmium, Chromium, Cobalt, Lead, Manganese, Mercury, Nickel, Selenium, Tin	Pad	Pads are extracted in a 17% nitric acid solution	ICP-OES & ICP-MS
TSNAs: NNN, NAT, NAB, NNK	Pad	Pads are extracted with water and solvent exchanged into methylene chloride	LC-MS/MS
PAAs: 1-Aminonaphthalene, 2-Aminonaphthalene, 3-Aminobiphenyl, 4-Aminobiphenyl	Pad	Pads are extracted with 5% HCl, and after adding of NaOH, the aromatic amines are extracted with hexane. The extract is then concentrated and derivatized with pentafluoropropionic acid anhydride	GC-MS (NCI)
PAHs: B[a]P	Pad	Pads are extracted in methanol. The extract is cleaned by passing it through a C18 cartridge after which the PAHs are eluted using toluene	GC-MS (EI)

3. Reduced Formation of Toxicants of Notable Public Health Interest

- The PHTP was designed to heat and not burn tobacco. As such, the PHTP aerosol has a very different chemical composition to cigarette smoke. The differences between the PHTP aerosol and cigarette smoke is shown in **Figure 2**. Cigarette smoke on the left has a brown colour when captured on a filter pad; by contrast, the aerosol of PHTP on the right is visibly different, reflecting the different chemical compositions.
- Table 2** shows the yields for "tar" (NFDPM)*, nicotine and carbon monoxide for the PHTP and the 3R4F reference cigarette comparator. The NFDPM produced by PHTP is principally composed of the aerosol former glycerol [data not shown].
- The low temperature heating of the tobacco in the PHTP (c. 350°C) results in a distinct shift in the composition of aerosol toxicants compared with a cigarette. In comparison to the cigarette, the toxicant levels in the PHTP emissions were substantially reduced across all chemical classes measured (**Table 3**). For the nine toxicants proposed by TobReg for mandated reduction in cigarette emissions [2], the mean reductions in the heated tobacco product aerosol were 87.2–99.9% per puff with an overall average reduction of 97.1% (**Figure 3**). For the abbreviated list of harmful and potentially harmful constituents (HPHCs) of smoke specified by the FDA Tobacco Products Scientific Advisory Committee (excluding nicotine) [3], reductions in the aerosol of the heated tobacco product were 68.8–99.9% with an overall average reduction of 95.7% (**Figure 3**).

Figure 2. Differences between 3R4F cigarette smoke and PHTP aerosol



Table 2 Standard analyte and constituent yields

ISO Intense Parameter	PHTP aerosol (mg/puff)	3R4F cigarette smoke (mg/puff)	% Reduction PHTP vs. 3R4F
NFDPM "tar" *	1.83	2.65	31
Nicotine	0.11	0.18	41
Carbon monoxide	0.04	3.01	99

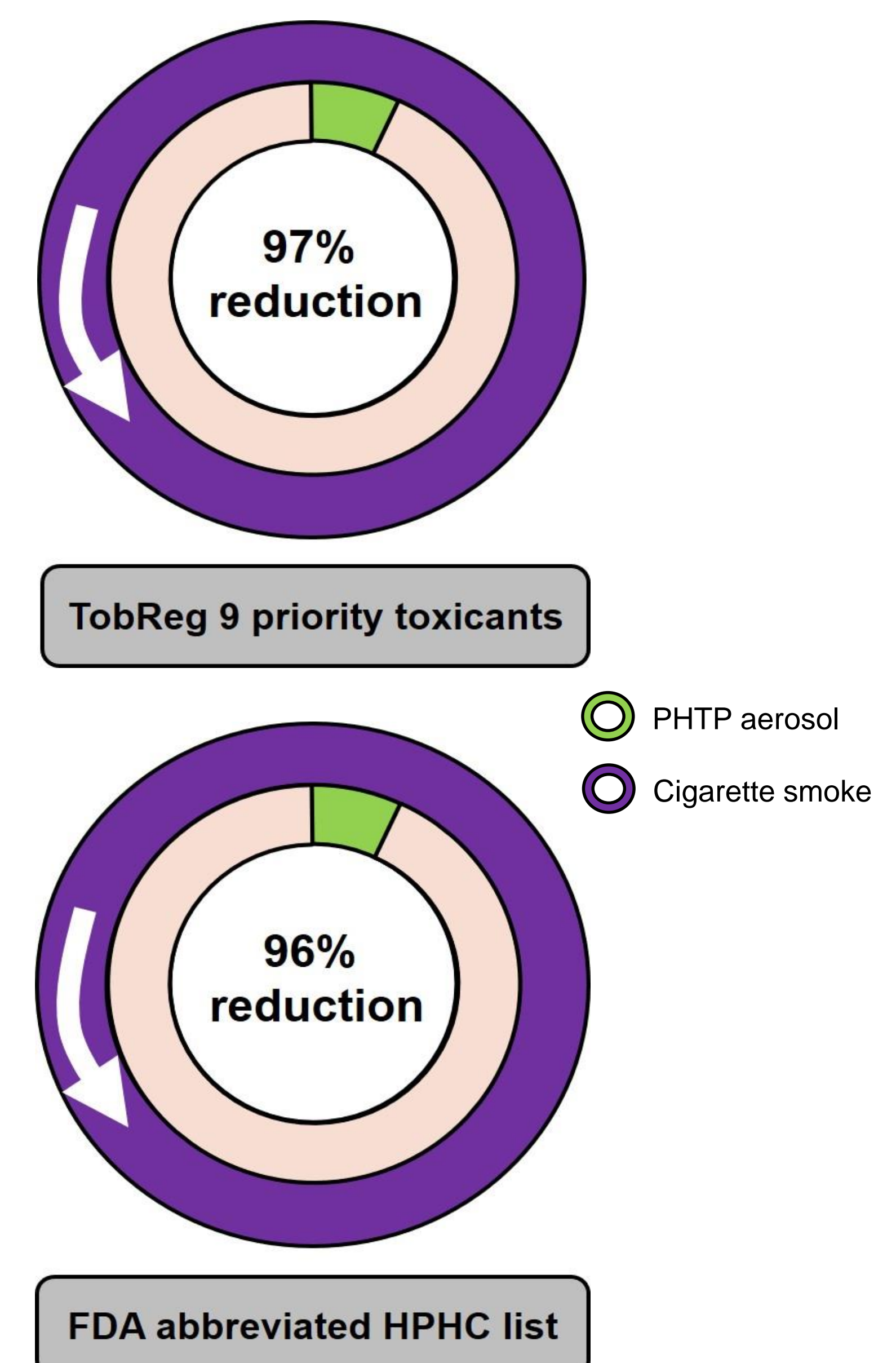
* "Tar" refers to the residue from cigarette smoke when a cigarette is burned and is the raw anhydrous nicotine-free condensate of smoke. "Tar" is calculated using the following formula: Tar = Total Particulate Matter – Nicotine – Water. Here we refer to the "tar" collected from the PHTP heated tobacco product as "nicotine-free dry particulate matter or NFDPM".

Table 3. Analytical characterization of PHTP aerosol and 3R4F reference cigarette smoke for select toxicants (µg/puff)

Analyte class	Compound	PHTP aerosol	3R4F cigarette smoke	% reduction PHTP aerosol vs. 3R4F cigarette smoke
TSNAs	NNN	0.0008	0.0292	97
	NAT	0.0017	0.0306	94
	NAB	0.0002	0.0037	95
	NNK	0.0005	0.0220	98
	TSNAs SUM	0.0032	0.0855	96%
Phenolics	Hydroquinone **	<0.3300	6.6952	>95
	Resorcinol	0.0117	0.2979	96
	Catechol	0.9115	8.5411	90
	Phenol	0.3883	0.8735	57
	p-Cresol **	<0.0367	0.6280	>94
	m-Cresol **	<0.0700	0.1280	>47
	o-Cresol **	<0.0633	0.1057	>42
Phenolics SUM	<1.8115	17.2697	>90%	
Ammonia	Ammonia	0.9906	3.1776	69%
PAHs	Benzo[a]pyrene **	<0.0003	1.3460	>99%
Carbonyls	Formaldehyde **	<0.2188	8.5559	>97
	Acetaldehyde	17.1592	133.5014	87
	Acetone	1.6587	47.1559	96
	Acrolein	0.4849	14.9512	97
	Propionaldehyde	0.8654	10.9320	92
	Crotonaldehyde **	<0.3647	4.2242	>91
	Ethylmethyl ketone	0.5354	11.6955	95
	Butyraldehyde	1.1646	6.2530	81
	Carbonyls SUM	<22.4516	237.2691	>91%
	PAAs	1-Aminonaphthalene **	<0.000028	0.0031
2-Aminonaphthalene **		<0.000020	0.0019	>99
3-Aminobiphenyl **		<0.000017	0.0005	>97
4-Aminobiphenyl **		<0.000017	0.0004	>96
PAAs SUM	0.000082	0.0059	99%	
Volatiles	1,3-Butadiene **	<0.0670	10.8582	>99
	HCN **	<0.1554	44.2541	99
	Methanol	17.2933	48.3016	64
	Ethylene oxide **	<0.0260	4.0656	>99
	Furan **	<0.6528	6.0611	>89
	Isoprene	0.1228	62.5698	99
	Propylene oxide **	<0.0346	0.2356	>85
	Acetonitrile	0.7022	35.0163	98
	Acrylonitrile **	<0.0394	2.8148	>99
	Vinyl acetate **	<0.0646	0.9000	>28
	Methane, nitro- **	<0.0396	0.1505	>74
	Benzene **	<0.0302	9.9967	>99
	Propane, 2-nitro- **	<0.0275	0.1683	>84
	Toluene	0.0668	18.1361	99
	Ethyl benzene **	<0.4230	2.1258	>80
Styrene	0.0158	1.2021	99	
Volatiles SUM	19.7608	246.0466	92%	

** Indicates some or all of the replicate values were below the limits of quantification for the PHTP; where below the LOQ, the LOQ value is used in calculation.

Figure 3. Average reduction in the formation of toxicologically relevant constituents in PHTP aerosol compared to levels measured in smoke from the 3R4F cigarette per puff



TobReg 9: acetaldehyde, acrolein, 1,3-butadiene, benzene, B[a]P, CO, formaldehyde, NNN, NNK
FDA abbreviated HPHC: TobReg 9 analytes + 1-aminonaphthalene, 2-aminonaphthalene, 4-aminobiphenyl, acrylonitrile, ammonia, crotonaldehyde, isoprene, toluene

4. Conclusions

- These results show that the tested PHTP produces a much simpler aerosol than cigarettes with relatively low levels of targeted cigarette smoke toxicants. Such products may offer the potential for substantially reduced exposure to toxicants when used as an alternative to cigarettes.

References

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