A preliminary comparison of flavoured waterpipe tobacco aerosol with cigarette smoke: Part 2: Hoffmann analytes machine derived data

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INTRODUCTION

Cigarette smoke is composed of thousands of toxicants produced by the combustion of tobacco at temperatures as high as 900^{O}C. Over the preceding decades, regulators, researchers and public health organisations have compiled lists of these toxicants, the most widely cited being the "*Hoffmann*" analytes and more recently the US Food and Drug Administration (FDA) Harmful and Potentially Harmful Constituents (HPHC).[1,2]

Smoking-related harm and disease are caused by long-term exposure to the toxicants found in combusted tobacco smoke. Accordingly, any nicotine product that can avoid combustion has the potential to be less risky than traditional combustible tobacco products. When comparing tobacco products, it is much more important to analyse the levels of individual toxicants that appear in the smoke or aerosol, since they are widely recognized as being relevant to the health effects of tobacco use.

In contrast to cigarette smoke, flavoured waterpipe tobacco aerosol is produced by heating at temperatures between 120^{O}C and 190^{O}C.[3,4] Consequently, its composition is fundamentally different from cigarette smoke, being composed primarily of glycerol, propylene glycol and carbon monoxide. Therefore, simplistic comparisons of Total Particulate Matter (TPM) yields between waterpipe and cigarettes do not provide meaningful information to inform an assessment of relative risk.

The aim of the present study was to further characterise Al Fakher "*Two Apples with Mint*" aerosol against forty one "*Hoffmann*" analytes (carbon monoxide, nicotine and NFDPM having been addressed in Part 1- STPOST24)[5], and assess exposures based on consumption patterns reported by Germany's Federal Institute for Risk Assessment (BfR) between waterpipe and the 3R4F cigarette.[6]

MATERIALS & METHODS

As described in STPOST24 "*A preliminary comparison of flavoured waterpipe tobacco aerosol with cigarette smoke: Part 1 NFDPM, nicotine and carbon monoxide machine derived yields.*"

Waterpipe Aerosol "*Hoffmann*" Analytes Analysis

In the absence of suitably validated analytical techniques specific for the measurement of "*Hoffmann*" analytes in waterpipe tobacco product aerosol, Global Laboratory Service (GLS) Inc. USA, adapted techniques used in the routine assessment of other tobacco product categories (Table 1.0). Al Fakher continues to work with GLS and other third-party laboratories to develop robust analytical techniques for the assessment of waterpipe tobacco aerosol.

Table 1.0: Analytical methods used by GLS for the determination of "*Hoffmann*" analytes in the machine derived Al Fakher "*Two Apples with Mint*" aerosol.

Method No.	Analytes	Description
LP-416	Arsenic, Cadmium, Chromium, Nickel, Lead, Mercury and Selenium	Determination of Heavy Metal Content in Tobacco by Inductively Coupled Plasma - Mass Spectroscopy (ICP-MS)
LP-705	NOx	Determination of NOx, Puff Counts, and TPM in Smoke Vapor Using the RM20D
LP-706	NFDPM	Determination of Nicotine-free Particulate Matter in Smoke Condensate
LP-710	Hydroquinone, Resorcinol, Catechol, Phenol, p-Cresol, m-Cresol and o-Cresol	Determination of Phenolic Compounds in Mainstream Tobacco Smoke Condensate
LP-711	Benzo[a]pyrene	Determination of Benzo[a]pyrene in Mainstream Cigarette Smoke and Tobacco by GC-MS
LP-713	Formaldehyde, Acetaldehyde, Acetone, Acrolein, Propionaldehyde, Crotonaldehyde, 2-Butanone and Butyraldehyde	Determination of Carbonyls in Mainstream Tobacco Smoke Condensate
LP-715	Ammonia	Determination of Ammonia in Mainstream Tobacco Smoke by Ion Chromatography with Suppressed Conductivity Detection
LP-716	1-Aminonapthalene, 2-Aminonapthalene, 3-Aminobiphenyl, and 4- Aminobiphenyl	Determination of Primary Aromatic Amines by GC-MS/MS
LP-717	Nicotine, Menthol, Propylene Glycol, Glycerol, Water, Diethylene Glycol and Ethylene Glycol	Determination of Nicotine, Menthol, Propylene glycol, Glycerol, Water, and of Diethylene glycol and Ethylene Glycol Impurities in E-Cigarette Formulations and Smoke/Vapor Samples
LP-724	Pyridine, styrene, Quinoline and Eugenol	Determination of Selected Semil-volatiles in Mainstream Cigarette Smoke using GC-MS
LP-741	NFDPM, Water and Nicotine	Cigar Smoking and Determination of Nicotine Free Dry Particulate Matter, Water, and Nicotine
LP-754	NNN, NNK, NAT, NAB	Determination of Tobacco-Specific N-Nitrosamines (TSNAs) in Mainstream Smoke by LC-MS/MS
LP-761	Hydrogen Cyanide	Determination of Hydrogen Cyanide in Mainstream Tobacco Smoke by Continuous Flow Analyzer
LP-714	1,3-Butadiene, Isoprene, Acrylonitrile, Benzene and Toluene	Determination of Selected Volatiles in Mainstream Cigarette Smoke using GC-MS

3R4F mainstream smoke yields were taken from the published scientific literature using the Health Canada Intense (HCI) machine smoking regime (Table 1.0).[7,8]

RESULTS OF NFDPM ANALYSIS

Table 2 demonstrates that **twenty-nine "*Hoffman*" analytes were not detected at quantifiable levels in aerosol derived from Al Fakher "*Two Apples with Mint*"**, including; NNN, NNK, NAT, NAB, Hydroquinone, Catechol, Resorcinol, p-Cresol, o-Cresol, 1-Aminonaphthalene, 2-Aminonaphthalene, 3-Aminobiphenyl, 4-Aminobiphenyl, Propionaldehyde, Butyraldehyde, Lead, Cadmium, Chromium, Arsenic, Mercury, Selenium, Pyridine, Styrene, Quinole, 1,3-Butadiene, Isoprene, Toluene, Acrylonitrile and Hydrogen Cyanide.

Twelve remaining "*Hoffmann*" analytes were detected in waterpipe aerosol at quantifiable levels, including; Benzo[a]pyrene, Phenol, m-Cresol, Formaldehyde, Acetaldehyde, Acetone, Acrolein, Methylethylketone, Crotonaldehyde, Nickel, Benzene, and Ammonia. However, with the exception of Nickel, **the concentration of these analytes (ng per ml) in waterpipe aerosol after a one hour session was reduced by ≥90% compared to smoke from a single 3R4F** (Table 2.0).

Table 2.0: "*Hoffmann*" analyte characterisation of Al Fakher "*Two Apples with Mint*" aerosol and a comparison with 3R4F cigarette smoke (ng per ml smoke or aerosol collected).

Analyte Class	"*Hoffmann*" Analyte	Concentration (ng per ml smoke or aerosol)		Reduction Versus 3R4F Cigarette (%)
		3R4F Reference Cigarette (HCI)	Al Fakher "*Two Apples with Mint*" (ISO 22486)	
Metals	Nickel	0.0000	0.0050	n.a.
	Lead	0.0580	0.0000	100.0
	Cadmium	0.1870	0.0000	100.0
	Chromium	0.0000	0.0000	n.a.
	Arsenic	0.0210	0.0000	100.0
	Mercury	0.0090	0.0000	100.0
	Selenium	0.0000	0.0000	n.a.
TSNA	NNN	0.5340	0.0000	100.0
	NNK	0.5310	0.0000	100.0
	NAT	0.5540	0.0000	100.0
	NAB	0.0630	0.0000	100.0
Phenolics	m-cresol	15.5370	0.0800	99.5
	p-cresol	6.4360	0.0000	100.0
	Phenol	24.2980	0.1400	99.4
	Hydroquinone	143.3060	0.0000	100.0
	Resorcinol	3.7190	0.0000	100.0
	Catechol	161.4880	0.0000	100.0
	o-Cresol	7.7850	0.0000	100.0
PAAs	1-Aminonaphthalene	38.8800	0.0000	100.0
	2-Aminonaphthalene	22.7500	0.0000	100.0
	3-Aminobiphenyl	7.6400	0.0000	100.0
	4-Aminobiphenyl	4.5800	0.0000	100.0
Carbonyls	Crotonaldehyde	79.5900	4.8000	94.0
	Formaldehyde	123.8400	1.2300	99.0
	Acetaldehyde	2118.3500	1.3800	99.9
	Acrolein	214.2400	0.1200	99.9
	Methylethylketone	272.2100	0.0400	100.0
	Acetone	987.9900	0.1300	100.0
	Propionaldehyde	222.4700	0.0000	100.0
	Butyraldehyde	148.8900	0.0000	100.0
Semi-Volatiles	Pyridine	56.2770	0.0000	100.0
	Quinole	0.8140	0.0000	100.0
	Hydogen Cyanide	666.6100	0.0000	100.0
Volatiles	Benzene	171.6260	2.5500	98.5
	1,3-Butadiene	156.5740	0.0000	100.0
	Isoprene	1802.7680	0.0000	100.0
	Acrylonitrile	58.3040	0.0000	100.0
	Toluene	283.7370	0.0000	100.0
	Styrene	28.9180	0.0000	100.0
PAHs	Benzo[a]pyrene	0.0231	0.00036	98.4
Nitrogenous	Ammonia	51.5600	3.1100	94.0

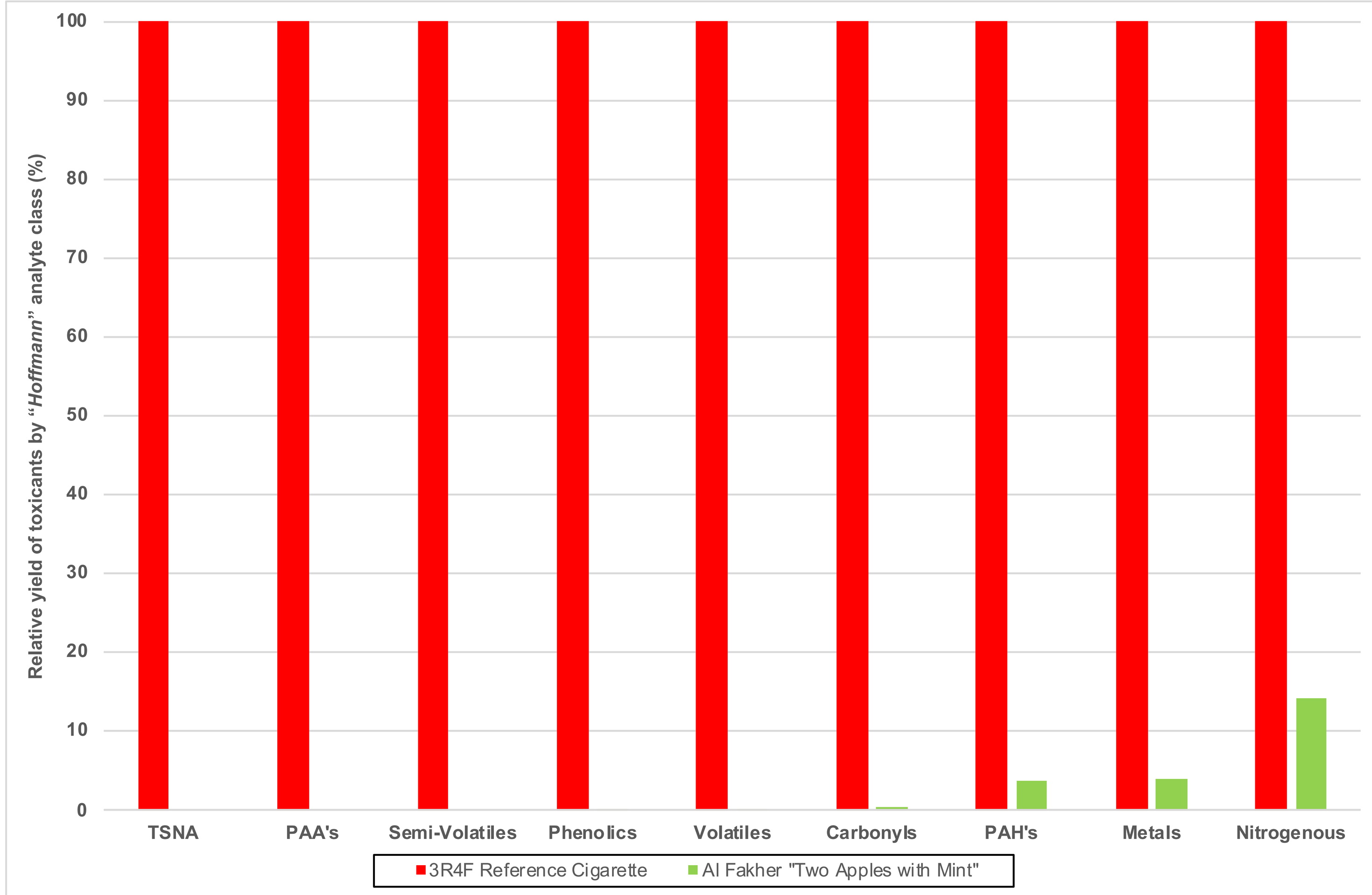
RELEVANCE OF ANALYSIS BASED ON CONSUMPTION PATTERNS

As with Part 1 (STPOST24), the NFDPM yield of a one hour waterpipe session were predictably greater than by a single cigarette so, again, consumption patterns over time must be factored in. Various studies find waterpipe to be characterised by intermittent and shared use.

According to the BfR "*Average consumers in Germany smoke between one and two waterpipes a week…*" compared to "*between 20 and 30 cigarettes a day*".[6] Using these consumption patterns i.e. 140 cigarettes and 2 waterpipe sessions per week, toxicant exposures based on machine derived yields may be calculated.

Using this approach, a ≥85% reduction in total yields of the "*Hoffmann*" analyte classes (TSNA, PAH's, Semi-Volatiles, Phenolics, Volatiles, Carbonyls, PAH's, Metals and Ammonia) was observed (Figure 1.0).

Figure 1.0: Relative yield of toxicants by "*Hoffmann*" analyte class from Al Fakher "*Two Apples with Mint*" compared to the 3R4F cigarette when BfR consumption patterns are taken into account.



CONCLUSION

Twenty-nine "*Hoffman*" analytes were not quantifiable in aerosol derived from Al Fakher "*Two Apples with Mint*". Three - NFDPM, nicotine and CO - were assessed in Part 1.

Twelve remaining "*Hoffmann*" analytes were detected in the aerosol at quantifiable levels, though with the exception of Nickel, their concentration was reduced by ≥90% compared to smoke from a single 3R4F cigarette.

When consumption patterns are considered, a ≥85% reduction in toxicant yields across the "*Hoffmann*" analyte classes (TSNA, PAH's, Semi-Volatiles, Phenolics, Volatiles, Carbonyls, PAH's, Metals and Ammonia) was observed.

Notably, higher concentrations of "*Hoffmann*" analytes linked to burning charcoal were observed which further indicates that the use of charcoal as the typical heating element should be subject of further research, product innovation and government policy.

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