DELIVERIES OF SMOKE CONSTITUENTS FROM CHARCOAL FILTER CIGARETTES WHEN SMOKED WITH VARYING INTENSITIES

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Objectives

- Evaluate the *"effectiveness"* of charcoal addition on the yields of Hoffman analytes when cigarettes are smoked under multiple regimes.

  - *demonstrated by comparison of yields from charcoal filter cigarettes to non-charcoal filter cigarettes*

- Identify factors or cigarette characteristics important in filter effectiveness for the brands selected in the study.

Study Design

- Products tested
  - Seven Canadian products with charcoal filters (CFC)
  - Three acetate filter cigarettes (CAC) including KR 3R4F

- Smoking Regimens

Condition	Puff Vol. (mL)	Interval (sec)	Duration (sec)	Vent Block (%)
ASR-1	25	60	2	0
ISO	35	60	2	0
ASR-3	45	50	2	0
ASR-4	45	30	2	0
CDN Mod	55	30	2	100
ASR-6	55	30	2	0

Smoke Collection and Analysis

TNCO + Filter Efficiency (T-115 + T-106)

- Tar
- Carbon Monoxide
- Nicotine
- Filter Efficiency

Volatiles (Expanded) (T-116 + TMS-124)

- 1,3-Butadiene
- Acrylonitrile
- Toluene
- Isoprene
- Benzene
- **Vinyl Chloride**
- **Acetamide**

Carbonyls (T-104)

- Formaldehyde
- Acetone
- Propionaldehyde
- MEK
- Acetaldehyde
- Acrolein
- Crotonaldehyde
- Butyraldehyde

Hydrogen Cyanide (T-107)

- Hydrogen Cyanide

PQS (Semi-Volatiles) (T-112)

- Pyridine
- Quinoline
- Styrene

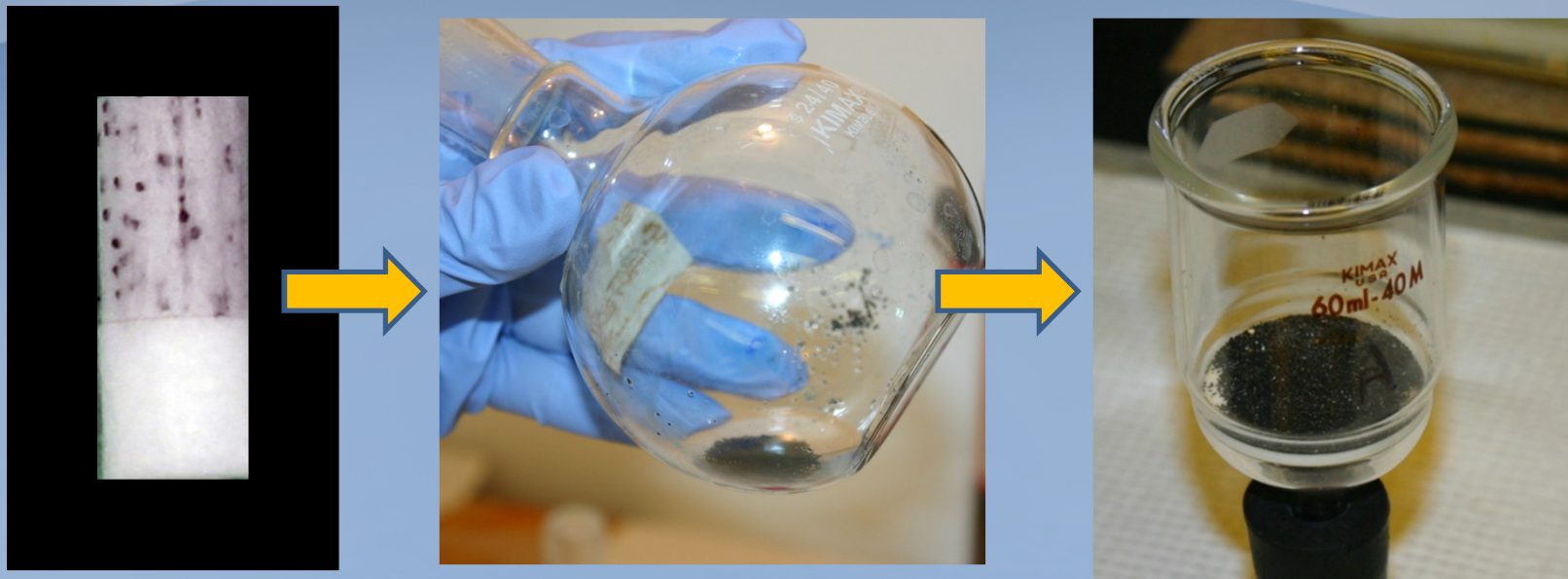## Free-Base Nicotine (TMS-138)

- Free-base Nicotine

Volatile Nitrosamines (TMS-125)

- NDMA
- NDEA
- NDBA
- NPYR
- NEMA
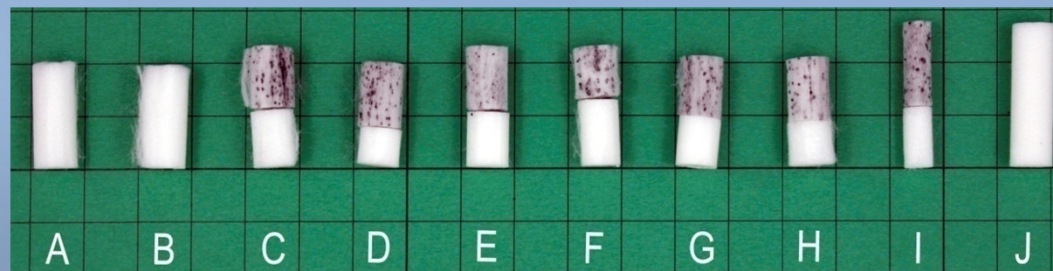- NDPA
- NPIP

< LOQ

For each analysis: n = 7

Determination of Charcoal Content

- 10 cellulose acetate filters containing carbon were dissolved in 100mL of dimethyl sulfoxide (DMSO) in order to separate the insoluble charcoal. The charcoal was recovered by filtration, washed with acetonitrile, dried and weighed.

Product Characterization

Product ID	Pressure Drop (mmH$_2$O)	Tip Ventilation (%)	Paper Porosity (mL/min/cm^2)	Charcoal in Filter (mg/filter)	Diameter (mm)	Total Filter Length (mm)	Acetate Portion (mm)	Charcoal Portion (mm)	Charcoal Conc. (mg/mm^3)
A	101	13	46	n/a	7.7	20	20	n/a	n/a
B	109	22	46	n/a	7.7	20	20	n/a	n/a
J	132	35	27	n/a	7.7	27	27	n/a	n/a
C	111	37	71	39	7.7	22	10.5	12.0	0.070
D	123	0	71	38	7.8	19	7.0	12.5	0.064
E	127	0	71	39	7.8	22	10.0	12.0	0.068
F	116	11	42	33	7.8	22	12.5	10.0	0.069
G	111	25	50	50	7.8	20	8.0	12.0	0.087
H	109	34	83	39	7.8	20	8.0	12.0	0.067
I	167	41	52	17	5.4	27	12.0	15.0	0.051

Presentation of Results

- Deliveries of Hoffmann analytes increased as the "*smoking intensity*" increased for both CFC and CAC.
  - *the total volume of smoke (mL/cig) which passes through a cigarette from the time it is lit until it is extinguished*

| Condition	C	D	E	F	G	H	I
ASR-1	199	171	183	186	222	216	165
ISO	263	223	236	251	292	287	219
ASR-3	371	304	327	330	403	406	315
ASR-4	505	409	434	449	562	558	425
CDN Mod	504	474	505	492	565	565	514
ASR-6	585	474	514	525	645	671	535

Example: Average Volume of Smoke (mL/cig) Taken for Tar Analysis

Presentation of Results

- Effect of smoking machine regime on analyte yield from the various charcoal brands can be illustrated using plots of analyte yield as a function of volume of smoke taken for analysis.
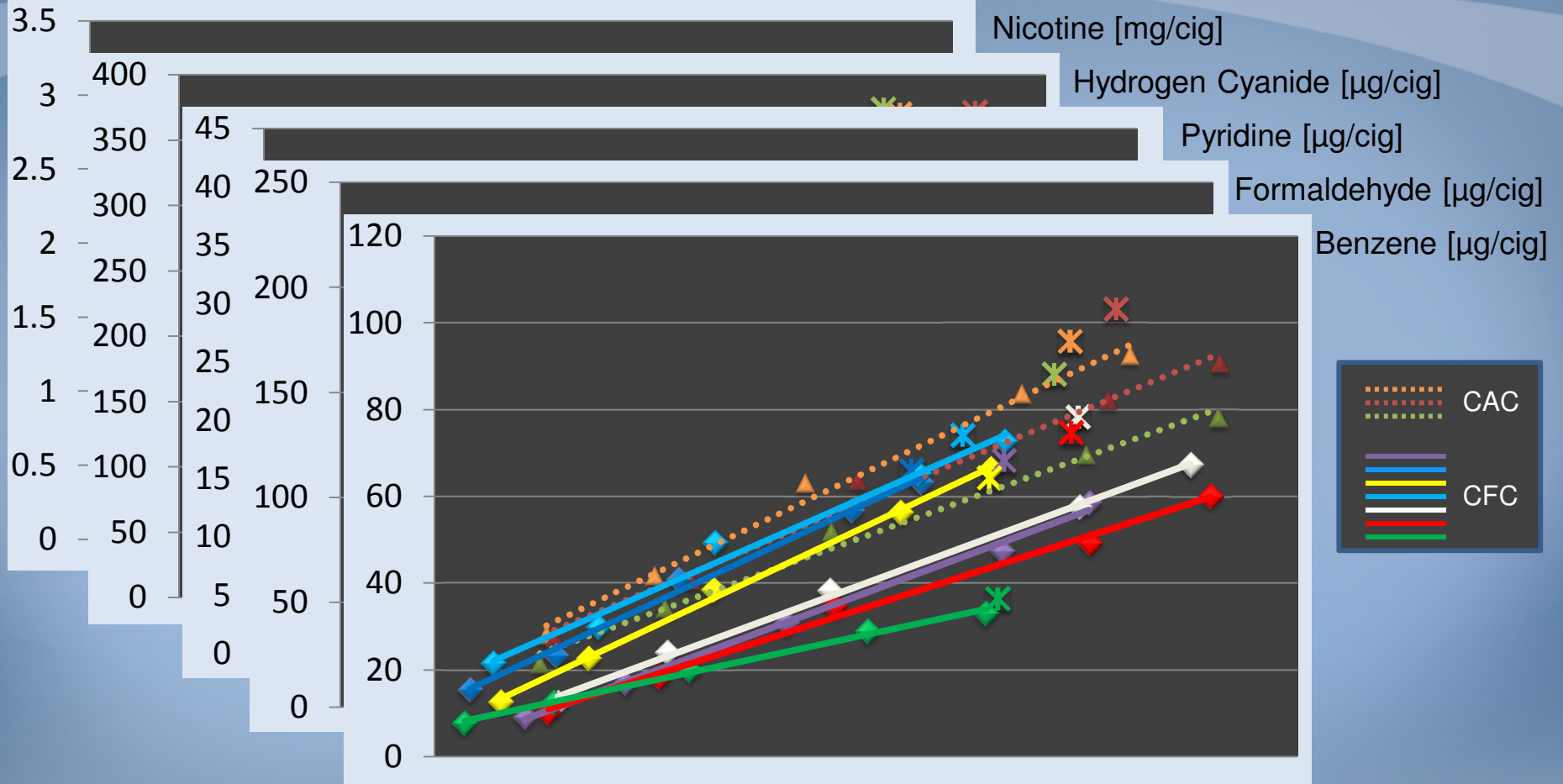
Filter *Effectiveness* in Relation to Smoking Regime
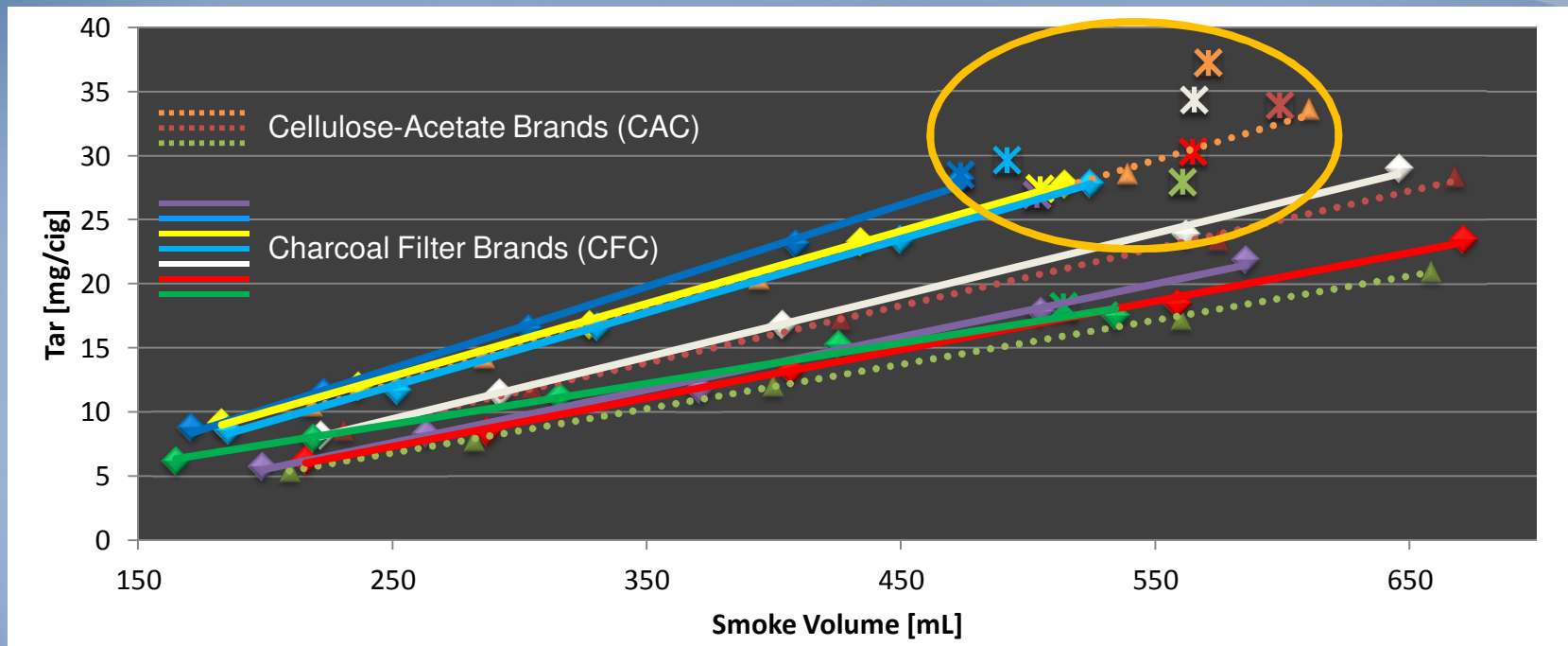
- A comparison of the slopes of the lines (amount of constituent/unit volume) could be made in order to assess the effect of the filter.

Filter *Effectiveness* (continued)

Identification of Factors Important in Filter Effectiveness

Multiple Regression Model

$$y = \beta_0 + \beta_1 FT + \beta_2 CFW + \beta_3 CFL + \beta_4 CFC + \beta_5 TV + \beta_6 PP + \beta_7 PDVO$$

where :

y is the analyte yield per L smoke

FT is the vector of _filter types_ where FT = 0 for non-charcoal and FT=1 for charcoal
CFW is the vector of _weights of the charcoal_ in each filter (mg/filter)
CFL is the vector of _lengths of each charcoal filter portion_ (mm/filter)
CFC is the vector of _concentrations of charcoal_ in each filter (mg/mm^3)
TV is the vector of percents (%) of _tip ventilation_
PP is the vector of _paper porosities_ (mL/min/cm2)
PDVO is the vector of _pressure drop_ in mm H$_2$O of the cigarettes without vent blocking.

Identification of Factors Important in Filter Effectiveness

| Compound	β_0	$\beta_1 \cdot FT$ (Filter Type)	$\beta_2 \cdot CFW$ (Charcoal Weight)	$\beta_3 \cdot CFL$ (Charcoal Filter Length)	$\beta_4 \cdot CFC$ (Charcoal Filter Concentration)	$\beta_5 \cdot TV$ (Tip Ventilation)	$\beta_6 \cdot PP$ (Paper Porosity)	$\beta_7 \cdot PDVO$ (Pressure Drop)
Pyridine	67.4	-	-	-1.78	-	-0.048	-	-0.118
Quinoline	3.25	0.896	0.041	-0.248	-	-0.014	0.008	-0.018
Styrene	44.1	21.8	-	-2.73	-	-0.269	-	-0.107
1,3 butadiene	170	-	-	-1.20	-	-1.92	-	-
Isoprene	1083	-	-	-	-	-9.79	-3.58	2.71
Acrylonitrile	35.4	-	-	-0.631	-	-0.307	-	-
Benzene	157	-	-	-3.40	-	-1.22	-	-
Toluene	275	-	-	-4.94	-	-1.62	-0.754	-
Vinyl Chloride	118	-	-	-1.23	-	-1.02	-	0.368
Acetamide	32.4	-	-	-	-	-0.264	-	-0.083

Multiple Regression Model Parameter Estimates

Summary – Filter Effectiveness

- For most of the volatiles examined, both charcoal filter length and tip ventilation are significant

- Increased filter length and increased tip ventilation are associated with a lower concentration (yield/litre)

- The very limited range covered by the variables suggests caution in interpreting the results. For example, 5 of the charcoal filter lengths were virtually identical. The fact that one brand had the longest filter and the lowest concentration may be responsible for much of the correlation.

Effect of Charcoal on
Filter Efficiency for Nicotine
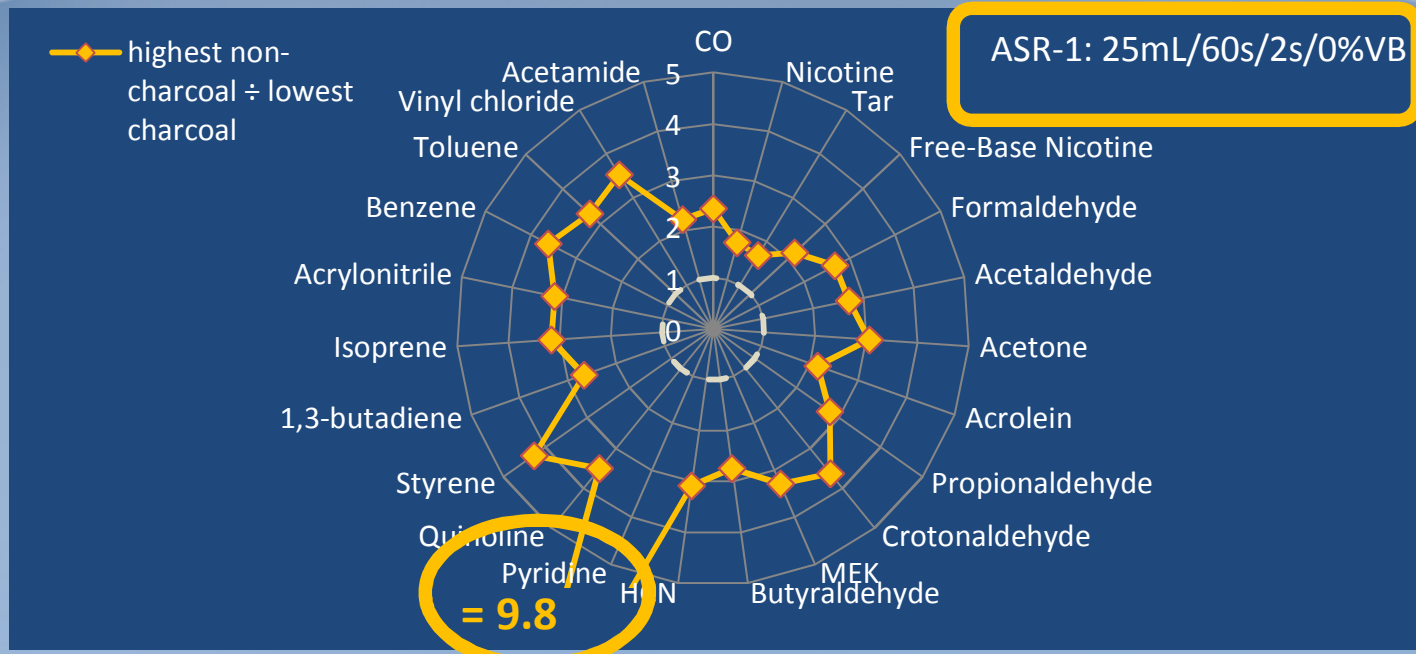
Multiple Regression Model Parameter Estimates
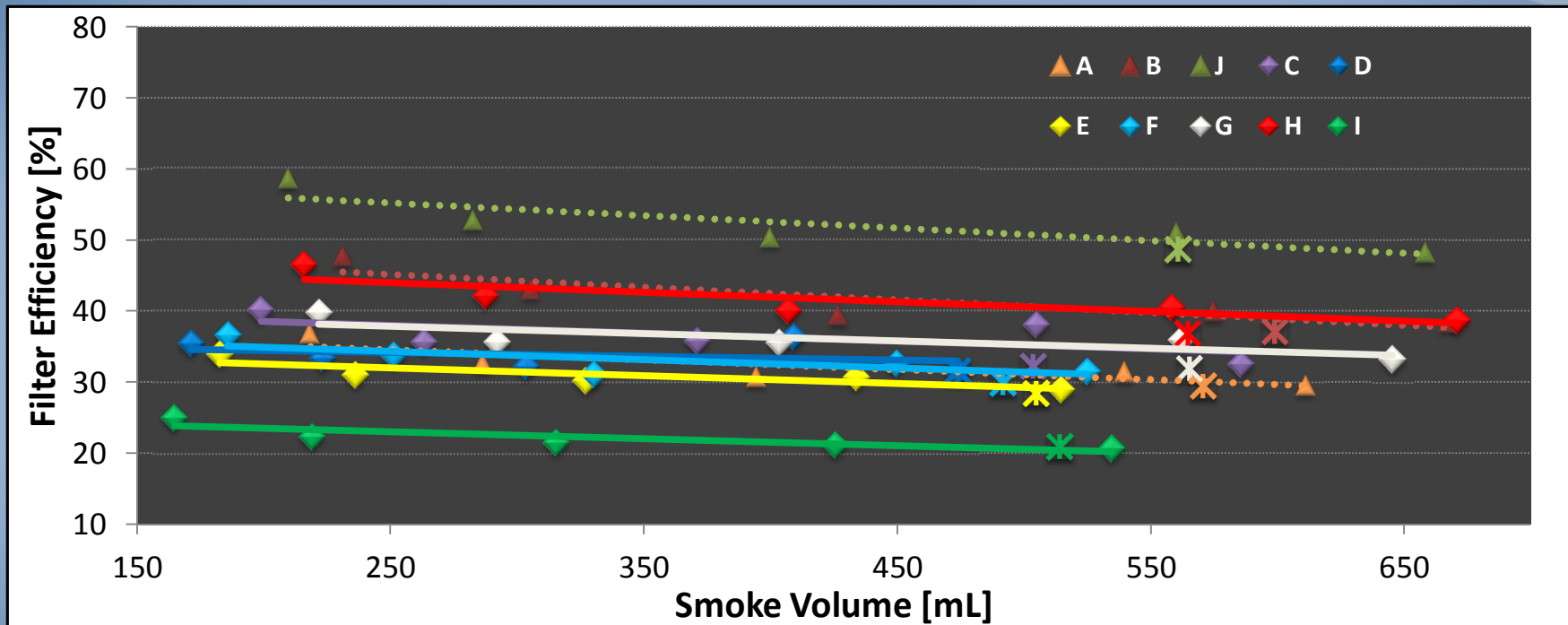
•Conversely, an increase in the concentration of charcoal (mg/mm3) is correlated with a decrease in filter efficiency (negative co-efficient).

Presentation of Results (continued)

- Compare results of CFC to the non-charcoal filter cigarettes.
  - *Demonstrate using most extreme yield differences*

- Compare results between brands for each analyte under each alternative smoking regime (ASR).

CFC versus CAC Comparisons

*Best Case Scenario - 'Light' Smoking
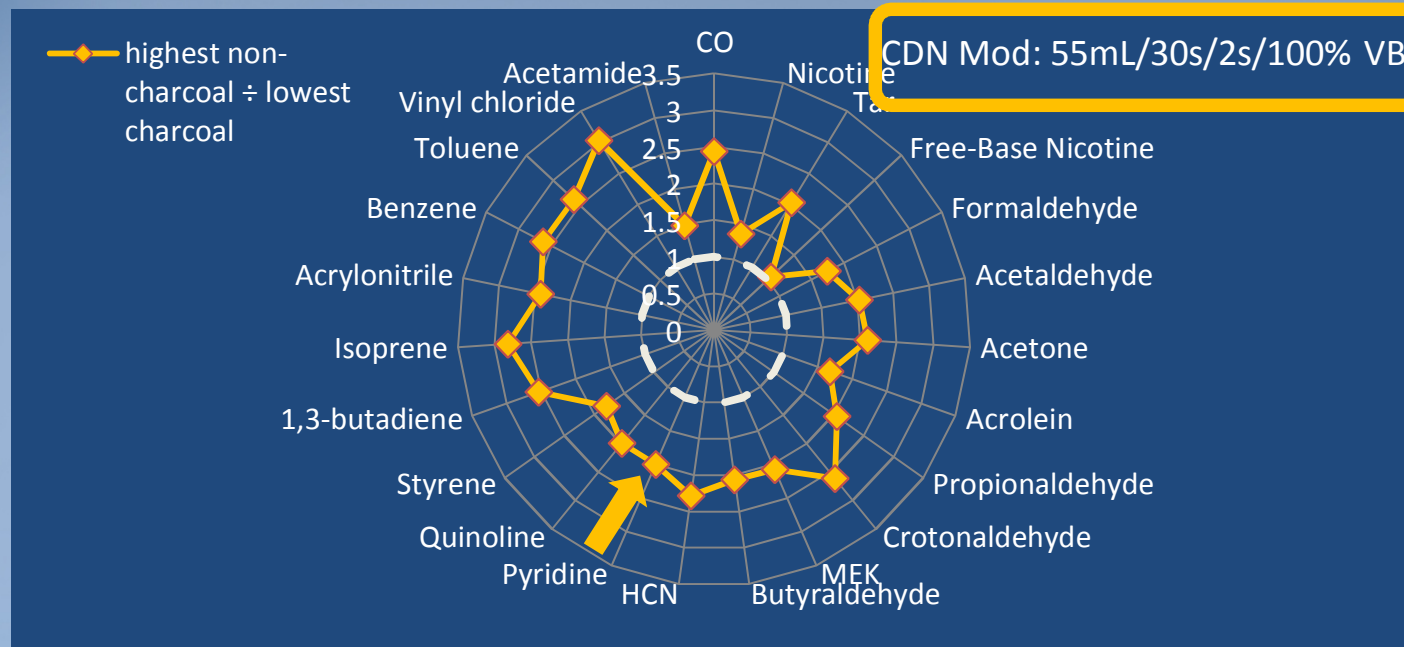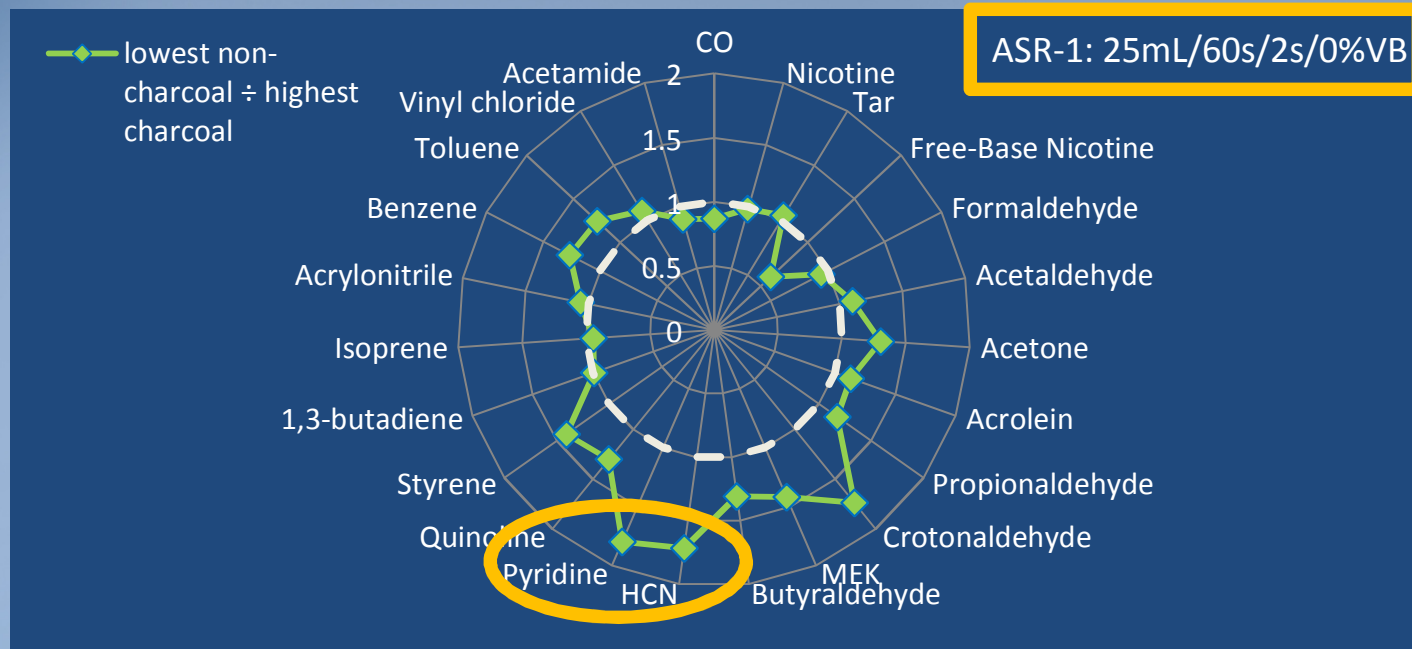

Worst cellulose-acetate brand

Best charcoal brand

*Highest cellulose-acetate filter brand yields <u>divided</u> by lowest charcoal filter brand yields

CFC versus CAC Comparisons

*Best Case Scenario – '*Extreme*' Smoking

highest non-charcoal ÷ lowest charcoal

CDN Mod: 55mL/30s/2s/100% VB

Labels around chart: CO, Nicotine, Tar, Free-Base Nicotine, Formaldehyde, Acetaldehyde, Acetone, Acrolein, Propionaldehyde, Crotonaldehyde, MEK, Butyraldehyde, HCN, Pyridine, Quinoline, Styrene, 1,3-butadiene, Isoprene, Acrylonitrile, Benzene, Toluene, Vinyl chloride, Acetamide

Axis values: 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5

Worst cellulose-acetate brand

Best charcoal brand

*Highest cellulose-acetate filter brand yields <u>divided</u> by lowest charcoal filter brand yields

CFC versus CAC Comparisons

*Worst Case Scenario - 'Light' Smoking

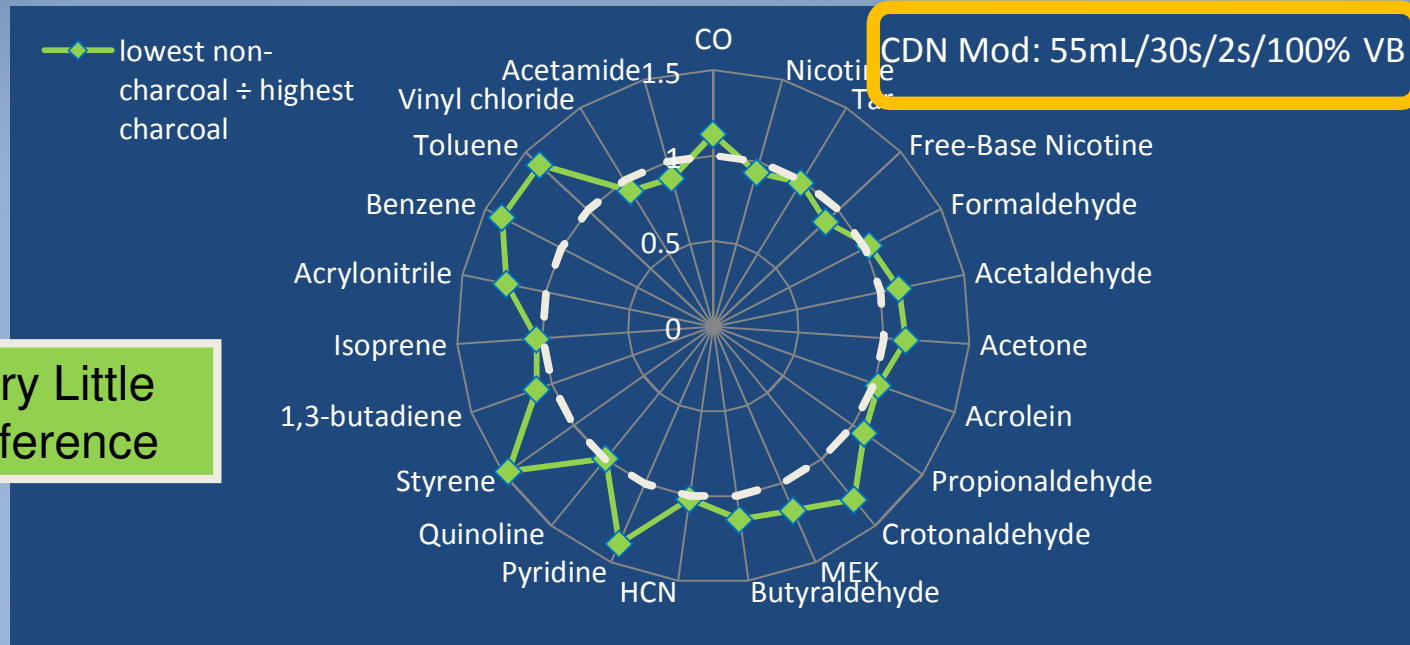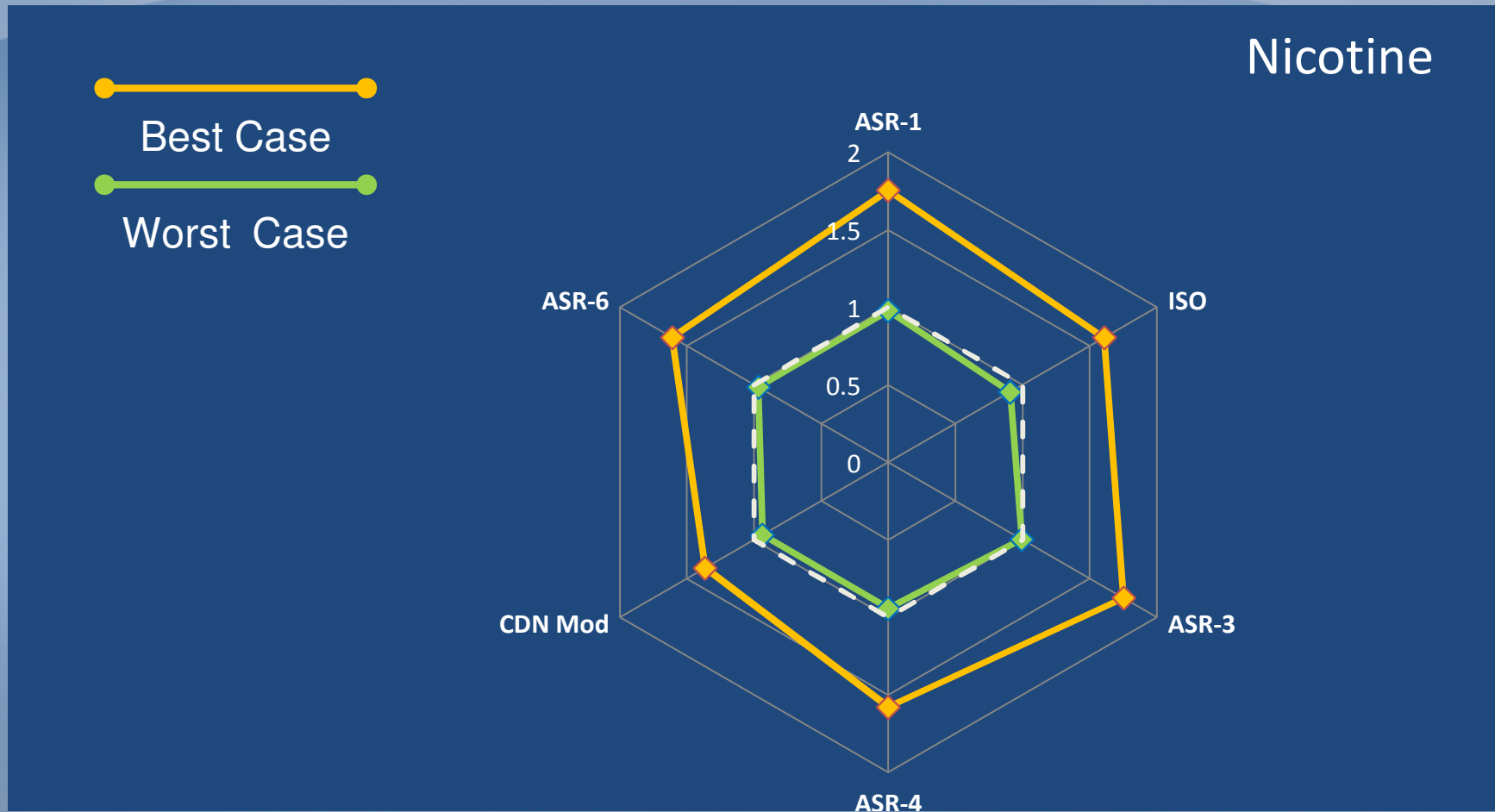ASR-1: 25mL/60s/2s/0%VB

Best cellulose-acetate brand

Worst charcoal brand

*Lowest cellulose-acetate filter brand yields <u>divided</u> by Highest charcoal filter brand yields

CFC versus CAC Comparisons

*Worst Case Scenario – '*Extreme*' Smoking

Legend: lowest non-charcoal ÷ highest charcoal

CDN Mod: 55mL/30s/2s/100% VB

Very Little Difference

Best cellulose-acetate brand

Worst charcoal brand

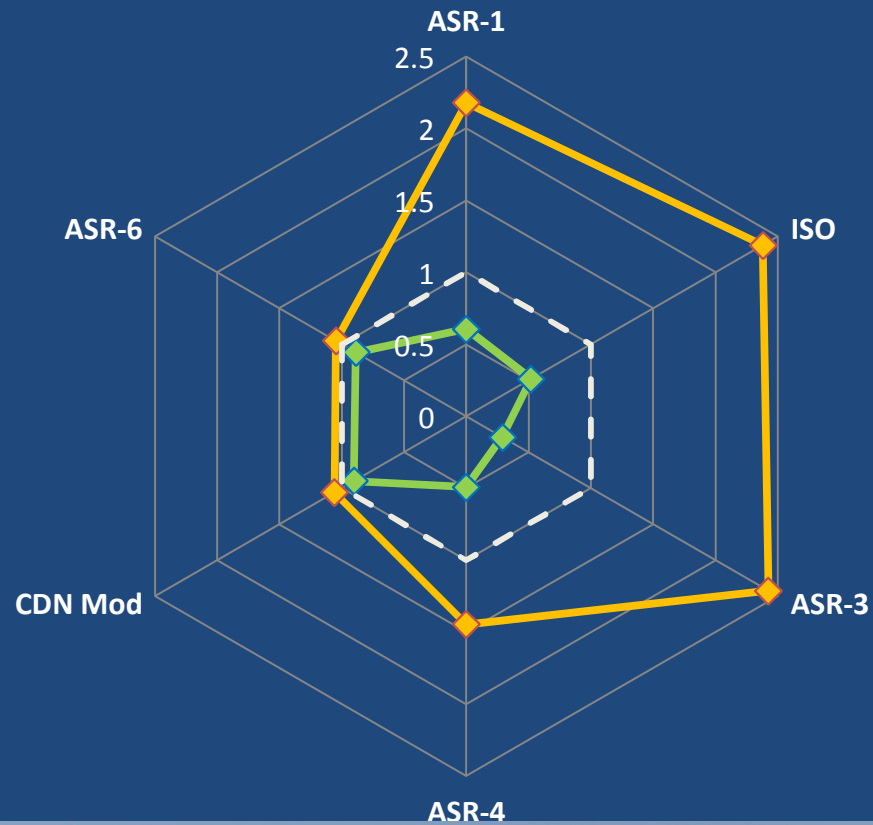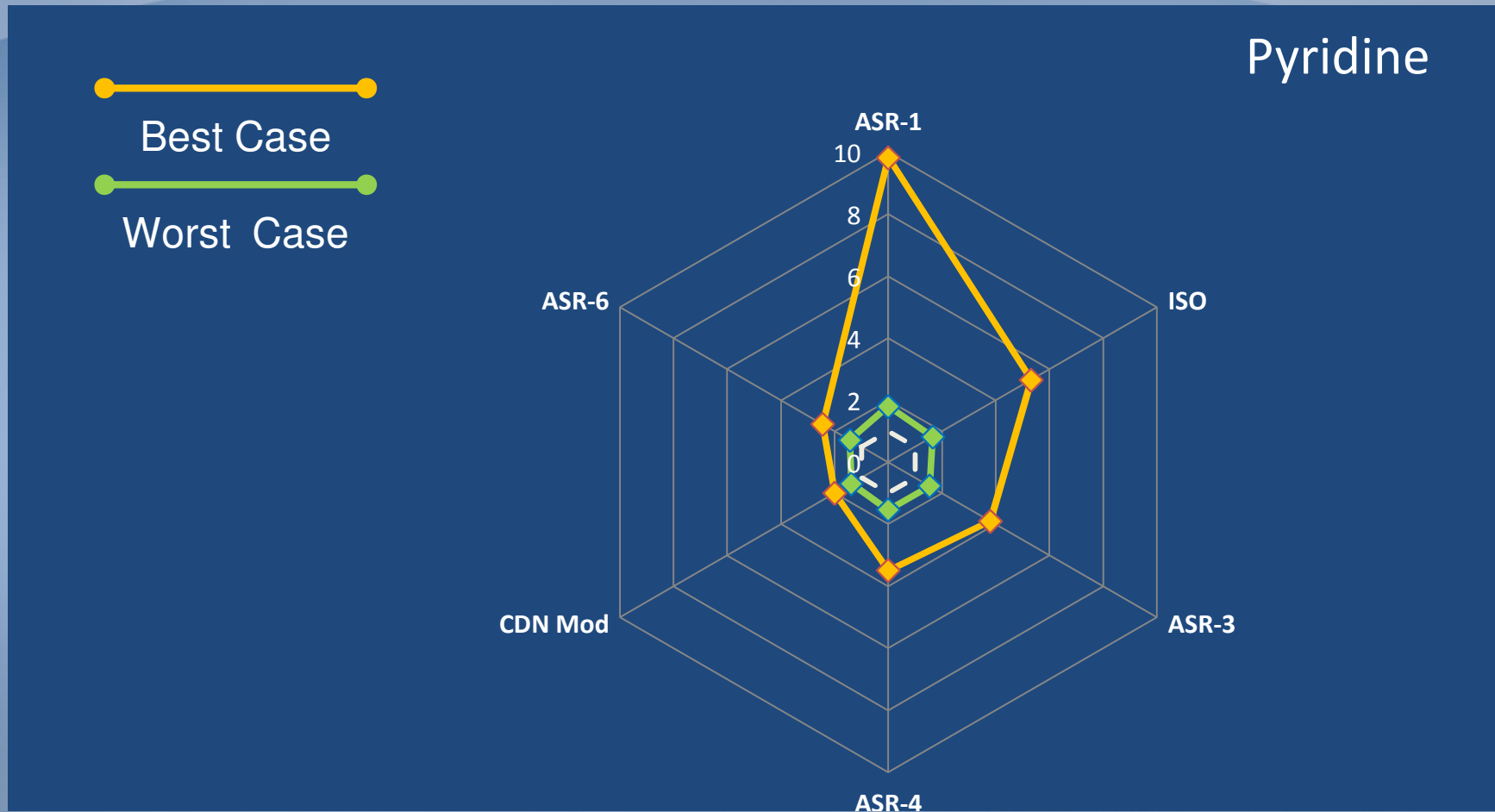*Lowest cellulose-acetate filter brand yields <u>divided</u> by Highest charcoal filter brand yields

Axis labels: CO, Nicotine, Tar, Free-Base Nicotine, Formaldehyde, Acetaldehyde, Acetone, Acrolein, Propionaldehyde, Crotonaldehyde, MEK, Butyraldehyde, HCN, Pyridine, Quinoline, Styrene, 1,3-butadiene, Isoprene, Acrylonitrile, Benzene, Toluene, Vinyl chloride, Acetamide

Scale: 0, 0.5, 1, 1.5

Regime Comparisons CFC versus CAC

Regime Comparisons CFC versus CAC

Regime Comparisons CFC versus CAC

Pyridine

Best Case

Worst Case

Regime Comparisons CFC versus CAC
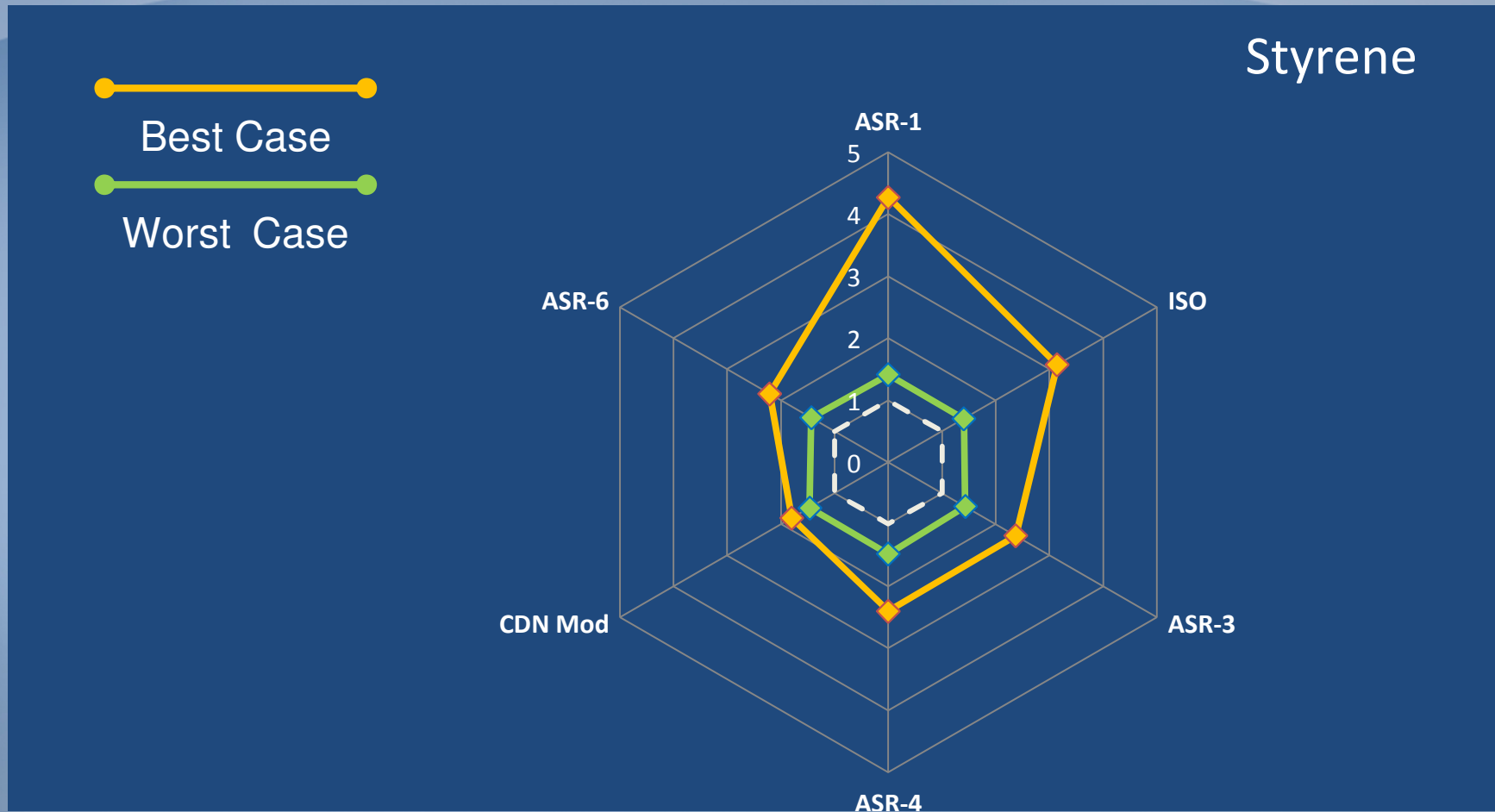
Conclusions

- In the 'best case' scenario, the ratio of the highest yield cellulose acetate filter brand to the lowest-yield charcoal filter brand is greater than unity (1) for the majority of analytes under all smoking regimes.

- The 'worst case' scenarios, with the ratio of the lowest-yield cellulose acetate filter brand to the highest-yield charcoal filter brand, indicate that the majority of analytes give results fairly close to unity (1) under all smoking regimes.

- For the majority of analytes, cigarettes with charcoal filters have, at best, lower analyte yields relative to cigarettes with regular cellulose acetate filters.

- At worst, cigarettes with charcoal filters appear to have similar analyte yields to those with regular filters.

Acknowledgement

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