
ARE THEY ALL INEFFECTIVE AND GIVE SMOKE THAT TASTES BAD?

John H. Lauterbach, PhD, DABT
Lauterbach & Associates, LLC
Macon, GA 31210 USA

Outline for presentation

- Background
- Objectives for the presentation
- Conclusions

Background

“What is remarkable, however, is the dreadful taste cigarettes with such filters develop in their later puffs.”

M. L. Reynolds, Brown & Williamson Tobacco Corporation
Influence of Filter Additives on Smoke Composition
Symposium on Physical Parameters Which Affect the
Composition of Cigarette Smoke
32nd Tobacco Chemists' Research Conference
Montreal, Canada
October 30, 1978

On describing cigarettes made with CA filters that had a zinc salt added to the plasticizer to reduce HCN deliveries

Objectives for the presentation

- Working definition of selective filtration
- Review the importance of selective filtration to the development of PREPS based on conventional cigarettes
- Review some of the patents issued since 1978 describing selective filtration where the effectiveness of the selectivity has been documented
- Estimate the effect of intensive smoking regimens on selective filtration

Working definition of selective filtration

- For the purposes of this presentation, selective filtration will be defined as reduction of the delivery of a toxicant in mainstream cigarette smoke (MSS) without significantly decreasing the mainstream nicotine delivery under a given smoking regimen

Note:

Ideally, selectivity should not be decreased as when products are tested under more intensive puffing conditions and/or the blocking of filter ventilation is required

Selective filtration & PREPS

- Some aspects of MSS toxicity can be addressed through blending and/or processing
 - Use of low TSNA tobaccos
 - Reduction of precursors through processing
 - Nitrate reduction
 - Protein reduction
- However, selective filtration required for others
 - Reduction of cytotoxic agents
 - Acrolein
 - HCN
 - Reduction of carcinogens
 - 1,3-butadiene
 - Acetaldehyde

Selective filtration to reduce MSS toxicity

- This is not a new topic
 - Examples date back at least to early 1960s
 - Chemical measurements
 - Biological measurements
- However, determining changes in MSS toxicity due to selective filtration may not be as easy as determining changes in MSS chemistry
- Showing changes through human biomonitoring may be even harder

MSS Chemistry -- $\mu\text{g}/40\text{ mL puff}$

	CA/Ch/CA	CA	No filter
Acetaldehyde	86 ± 6	144 ± 9	113 ± 7
Isoprene	20 ± 2	76 ± 6	67 ± 4
Propionaldehyde	4.5 ± 0.4	12 ± 1	9.9 ± 0.6
Furan	3 ± 0.3	6.9 ± 0.5	5.6 ± 0.4
Acetone	21 ± 2	65 ± 4	52 ± 3
Acrolein	5.5 ± 0.4	18 ± 1	14 ± 1
Methyl furan	1.9 ± 0.2	8.4 ± 0.7	7.1 ± 0.5
Methyl ethyl ketone	4.3 ± 0.4	18 ± 1	15 ± 1
Butenone	1.4 ± 0.2	6.1 ± 0.3	4.9 ± 0.3
Benzene	3 ± 0.3	11 ± 1	10 ± 0.7

Adapted from Newsome, Norman & Keith 1965 TCRC, Paper #26

MSS cytotoxicity with KB cells

Cigarette A = CA/Carbon/CA

Cigarette C = No filter

Cigarette B = CA/Empty/CA

Table 1. Inhibition of growth of KB cells by gas phase, aerosol phase, and total condensate of cigarette smoke. The results are the means of six sets prepared for each factor compared. The numbers in parentheses indicate the range.

Factor compared	Type			Results of <i>t</i> -test (<i>p</i> -values)		
	A	B	C	A vs. B	A vs. C	B vs. C
			<i>Total smoke</i>			
ID ₅₀ per cigarette	318 (295-370)	654 (590-715)	768 (665-910)	< .001	< .001	.01-.025
Condensate per cigarette (mg)	39.8 (25.3-47.1)	43.3 (36.8-49.6)	53.8 (51.7-57.9)	.2-.4	.001-.005	< .001
ID ₅₀ /mg condensate	8.3 (6.7-12.1)	15.2 (14.3-16.0)	14.3 (11.9-17.4)	< .001	< .001	.2-.4
			<i>Gas phase</i>			
ID ₅₀ per cigarette	143 (100-205)	351 (300-400)	349 (310-385)	< .001	< .001	>0.50
Condensate per cigarette (mg)	14.3 (10.7-16.7)	13.5 (11.0-16.7)	14.3 (9.4-16.0)	> 0.50	>0.50	>0.50
ID ₅₀ /mg condensate	9.9 (8.9-12.3)	26.2 (23.0-30.4)	25.0 (22.2-33.0)	< .001	< .001	>0.50
			<i>Aerosol phase</i>			
ID ₅₀ per cigarette	189 (145-270)	297 (250-335)	463 (345-625)	~ .001	< .001	.001-.005
Condensate per cigarette (mg)	24.4 (18.7-28.6)	26.8 (22.1-32.0)	34.7 (30.8-41.1)	.2-.4	~ .001	~ .005
ID ₅₀ /mg condensate	7.7 (6.5-9.5)	11.1 (10.5-11.6)	13.5 (8.4-17.6)	< .001	.001-.005	~ .10

Cytotoxicity in both TPM & GVP

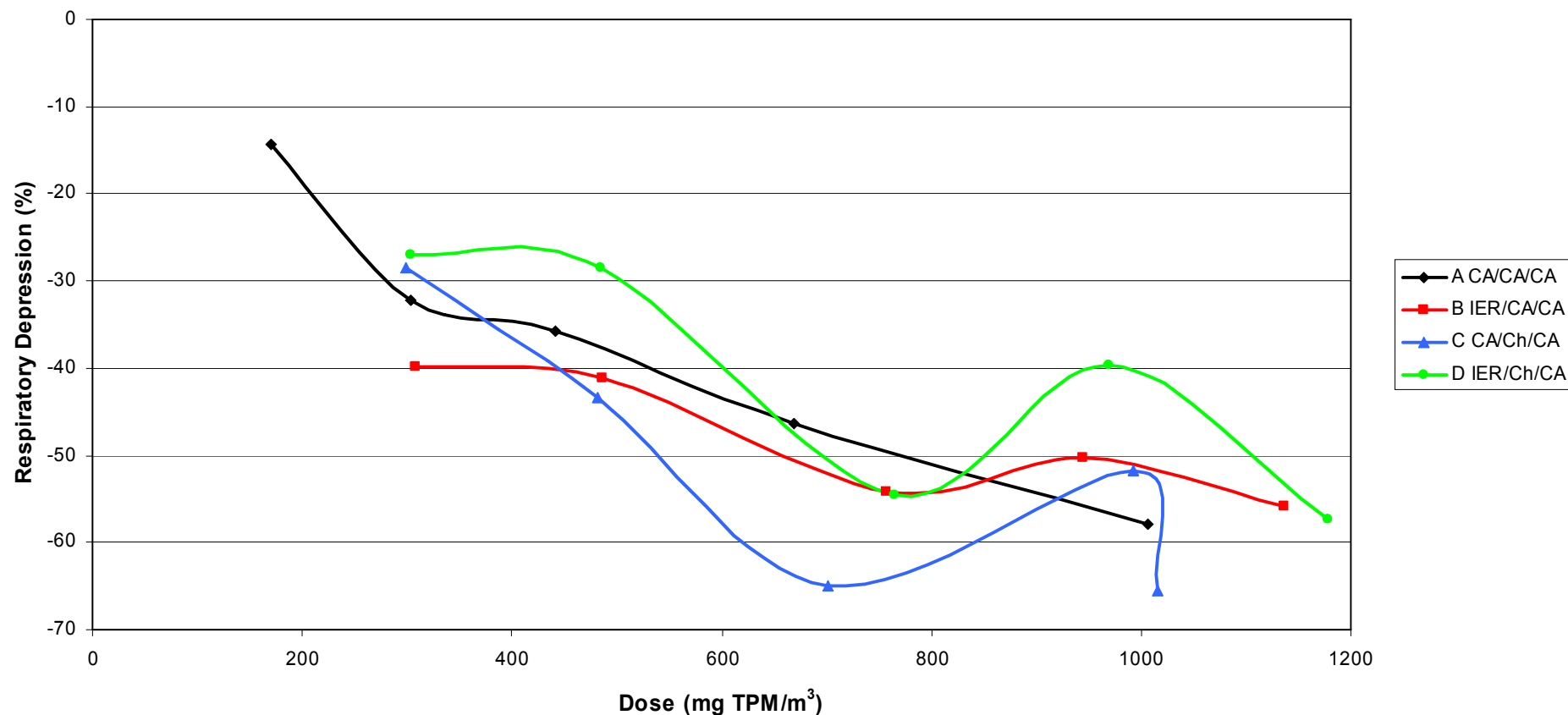
- Equal weights of particulate matter (TPM) had different biological activity when Cambridge filter trapped materials (e.g., TPM) were compared
 - TPM from nonfilter cigarette had similar toxicological properties to CA-filtered TPM
 - TPM from cigarette with CA/Ch/CA filter less toxic than TPM from CA-filtered product
 - This implied that charcoal adsorbed semivolatile toxic materials that were in rapid equilibrium between particulate and gas-vapor phases
 - Differences in toxicity could have been due to differences in TPM concentrations of cyanohydrins

Measuring effectiveness of selective filtration

- Human biomonitoring may be best approach
 - Takes into account different smoking behaviors
 - Difficult to do correctly, costly, and time-consuming
- More traditional approach beginning with MSS chemistry under normal and intensive conditions including block of filter ventilation, if any
- Traditional approach also includes *in vitro* and *in vivo* toxicology assays
 - Assays used under both ISO & intensive regimens
 - Sometimes unexpected results occur
 - Changes in procedures analytical vs. bioassay
 - Changes in rodent breathing rates with changing composition

Changes in rat RD₅₀ values with different filters

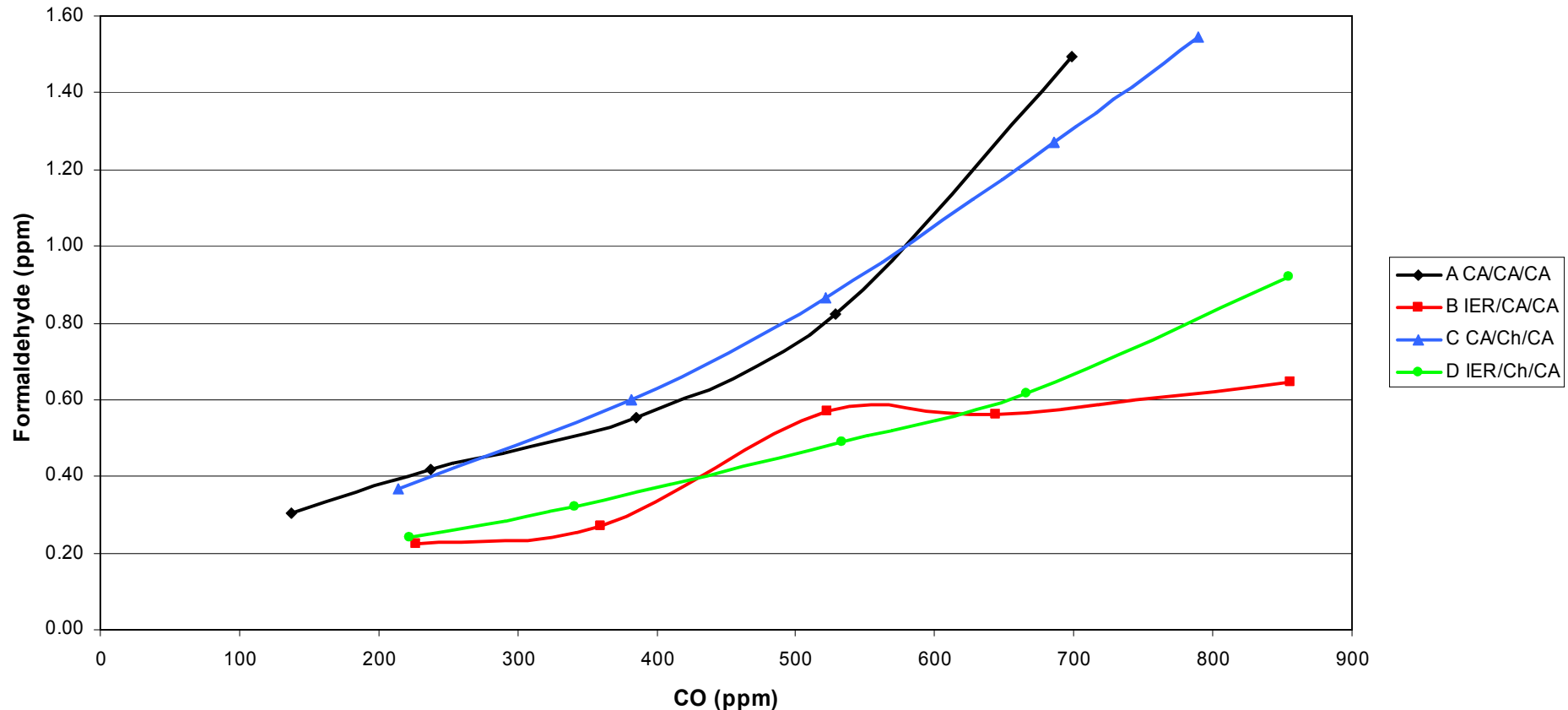
Respiratory depression (%) versus Dose (mg TPM/m³)



Source: Lauterbach, "Effects of Selective Filtration on Rodent Respiratory Depression," 58th Tobacco Science Research Conference, September 2004, Paper #65

Are likely the result of differences in chemistry

Formaldehyde (ppm) versus CO (ppm)



Source: Lauterbach, "Effects of Selective Filtration on Rodent Respiratory Depression," 58th Tobacco Science Research Conference, September 2004, Paper #65

Selective filtration materials then and now

- In his 1978 Symposium paper, Lance Reynolds listed the following selective filtration materials as being in commercial use in 1977
 - Cellulose acetate
 - Triacetin & triethylene glycol diacetate
 - Polyethylene glycol
 - Activated carbon
 - Modified Duolite A-7 (ion exchange resin)
 - Magnesium silicate
- Is this list any different today?

No new selective filter materials in use?

- While there are numerous patents issued and pending for selective filtration, nothing apparently in commercial use other than different varieties of carbon
- Cost and time for getting new materials qualified may be one reason for lack of commercial introduction
- Another reason may be degradation in filter performance when cigarettes tested under Massachusetts and Health Canada regimens

Examples from patent literature

- Hard to find recent literature that gives detailed smoke chemistry along with nicotine deliveries
 - Cost of detailed analyses
 - May not show effectiveness of technology
 - Biological data apparently not given
- Reductions in toxicant:nicotine ratios under different smoking regimes important as those ratios used as measures of effectiveness
- Apparently no examples in patent literature with details on selective filtration under intensive conditions

Patent example – US 5,839,339

Description	Control	Test
Filter	Conventional	Gathered Web, 50% carbon
Tob. Column Length, mm	57	57
Filter Length, mm	27	27
Filter segment length, mm	—	17 + 10
Air Dilution, %	21.5	50.8
Cigarette pressure drop, mm of water	127	102
<u>FTC SMOKE DATA</u>		
Puffs/cigt.	7.9	7.9
WTPM, mg	11.8	11.6
Tar, mg	9.9	9.6
Nicotine, mg	0.75	0.92
CO, mg	11.4	7.1
CO/TAR Ratio	1.15	0.74
<u>MS CARBONYLS</u>		
Formaldehyde, μg	9.8	7.3
Acetaldehyde, μg	667.8	118.5
Acetone, μg	296.2	32.3
Acrolein, μg	68.7	15.5
Total Carbonyls	1042.5	173.6
<u>OTHER MS DATA</u>		
NO _x , μg	198.2	42.3
HCN, μg	163.9	29.1
NH ₃ , μg	22.06	12.59

Banerjee *et al.*, “Low CO Cigarette,” November 24, 1998

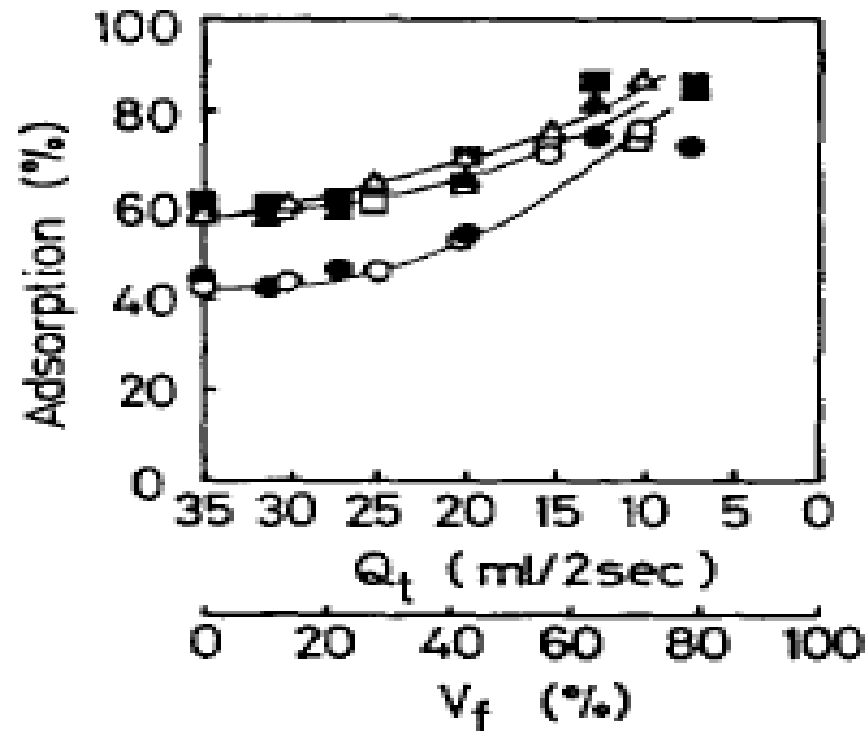
Patent application publication – US 2005/0257798 A1

- Treated PUF filters
 - Solvent extracted to remove impurities
 - Form “plurality of reactive radicals”
- Smoking procedure
 - Repeated 30-40 mL puffs smoked into impinger cooled in liquid argon
 - No puff count data given but “approximate sampling time was 1 minute”

Summary of Percentage of Total Polynuclear Aromatics Absorbed by PUF Filter					
Compound	Experiment 1 Cigarette Filter: YES PUF Filter: YES	Experiment 2 Cigarette Filter: YES Cigarette Completely Burned and Cigarette Filter Slightly Burned	Experiment 4 Cigarette Filter: PARTIAL PUF Filter: YES	Average of Percentage of Total Amount Absorbed by PUF Filter	
				Average	Standard Deviation
2-methylnaphthalene	72%	68%	74%	71%	2%
Acenaphthylene	60%	62%	40%	54%	10%
Acenaphthene	65%	70%	86%	74%	9%
Dibenzofuran	75%	77%	87%	80%	5%
Fluorene	68%	64%	80%	71%	7%
Phenanthrene	59%	65%	78%	67%	8%
Anthracene	47%	21%	80%	49%	24%
Carbazole	24%	26%	53%	34%	13%
Fluoranthene	27%	26%	60%	38%	16%
Pyrene	24%	23%	57%	35%	16%
Benzo(a)anthracene	0%	22%	49%	24%	20%
Chrysene			61%	61%	0%
Total Polynuclear Aromatics [†]	62%	59%	74%	65%	6%
Tar	10%	14%	18%	14%	3%
Nicotine	26%	23%	25%	25%	1%
Cotinine	0%	15%	17%	11%	8%

Hsu, “Filter capable of trapping carcinogens ...,” November 24, 2005

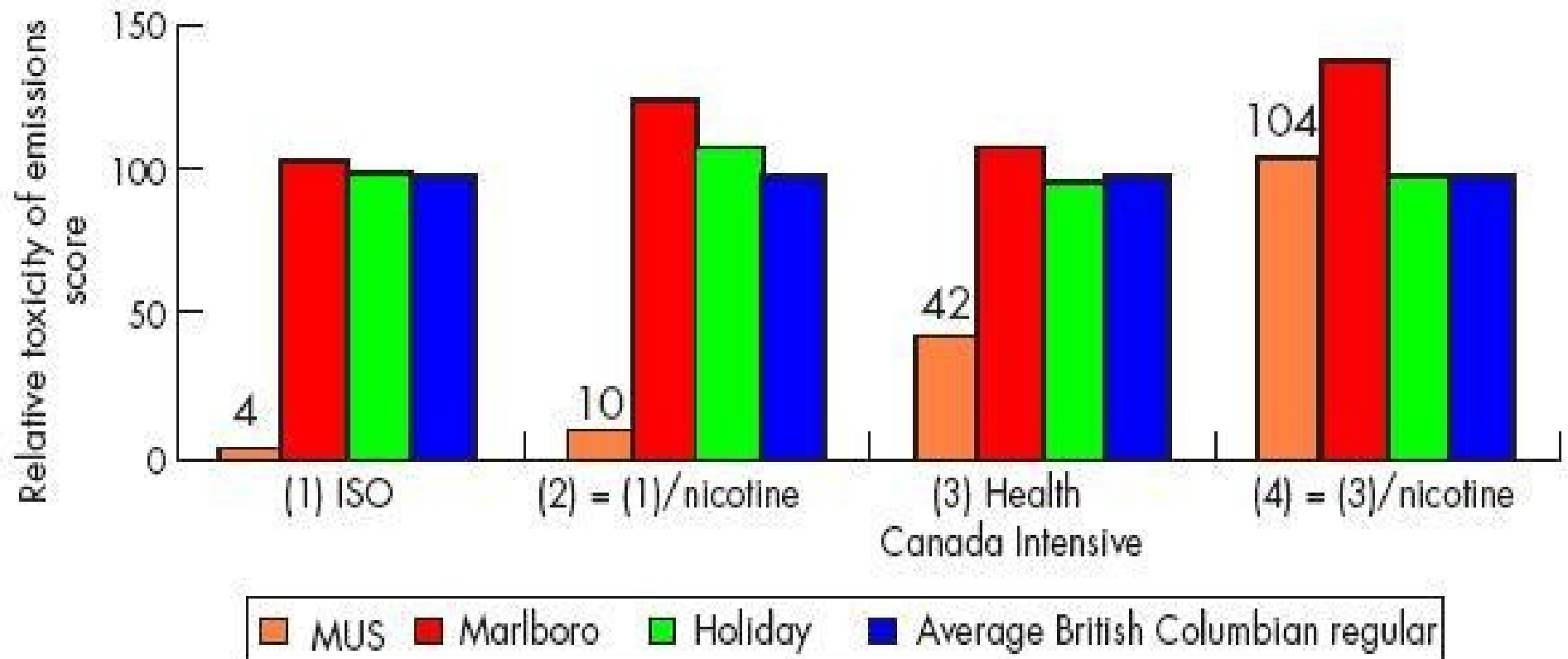
Charcoal efficiency and flow



○, acetaldehyde; △, isoprene; □, acetone. The adsorptions of acetaldehyde (●), isoprene (▲) and acetone (■) by the vented charcoal filter with a 10 mm charcoal layer is plotted against V_f on a reversed scale to Q_t .

Adapted from Tokida *et al.*, *Agric. Biol. Chem.* 1985;49:3109-13

ISO versus Health Canada smoking regimen



Adapted from Laugesen & Fowles, *Tobacco Control*, October 2006

Conclusions – 1

- Almost thirty years after the Lance Reynolds 1978 review, there appears to have been little change in the materials used to achieve selective filtration
 - Resources required for qualification of new materials
 - Performance under intensive smoking regimes
- While numerous patents issued for selective filtration, data to show that they give decreases in toxicant concentrations not accompanied by decreases in nicotine concentration may not be available for intensive smoking conditions

Conclusions – 2

- Very recent article by Laugesen and Fowles presented data that showed difficulty of achieving meaningful selective filtration under Health Canada smoking conditions
- Laugesen and Fowles expressed doubts as to whether meaningful toxicity reductions could be achieved through use of selective filtration