Regional Lung Deposition of Tobacco Smoke

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Background

- Deposition efficiency of mainstream tobacco smoke = 60-80% (Baker review of exhale capture studies)
- Deposition efficiency of ETS / aged sidestream smoke generally lower = 11 – 55% (exhale capture studies by Hiller, McAughey, Morawska)
- Deposition efficiencies generally greater than expected for measured diameter of particles
  - 180–860 nm (MS)
  - 100–300 nm (ETS/aged SS)
- Numerous mechanisms to explain enhanced MS deposition efficiency but no modelled fit
  - Coagulative growth
  - Hygroscopic growth
  - Cloud behaviour
- Review of radiotracer studies to offer insight to mechanisms with respect to smoke, smoking and inhalation behaviour
- Radiotracer studies conducted at the Harwell Laboratory, UK in the early to mid 1990s
- Conclusions are those of the author; not the sponsors

Physical Processes Controlling Smoke Deposition in Lung

- Smoke
  - Particle size
  - Chemical variation
    - solubility
    - vapour pressure
    - hygroscopicity
  - Physical variation
    - coagulation
    - ΔT & ΔH
    - cloud behaviour
    - evaporation
    - condensation
- Human
  - Breathing pattern
    - depth
    - flow
    - duration
  - Puff parameters
  - Physiology
    - disease
    - gender
    - laryngeal compression
    - ventilation asymmetry
    - intra- versus inter-individual behaviour

Radiotracers

Mainstream smoke

- ^{123}I-1-iodohexadecane ($C_{16}H_{33}I$)
- B.Pt. = 380^{o}C (equivalent to average boiling pt. reported for tar condensate
- Injected down length of tobacco rod in dichloromethane solution
- Decay half-time = 13.2 hours
- γ-emission of 160 keV

Pritchard et al, J. Aerosol Sci. ***19*** *715-724 (1988)*

Aged & diluted SS

- ^{212}Pb
- Labelling *in situ* with pulse of ^{220}Rn (thoron) gas (from ^{228}Th) introduced into chamber with aged SS
- Rapid decay via ^{216}Po to ^{212}Pb
- Decay half-time = 10.6 hours
- γ-emission of 240 keV

Strong et al, J.Aerosol Sci. ***25*** *199-207 (1994)*

Study design

Mainstream smoke

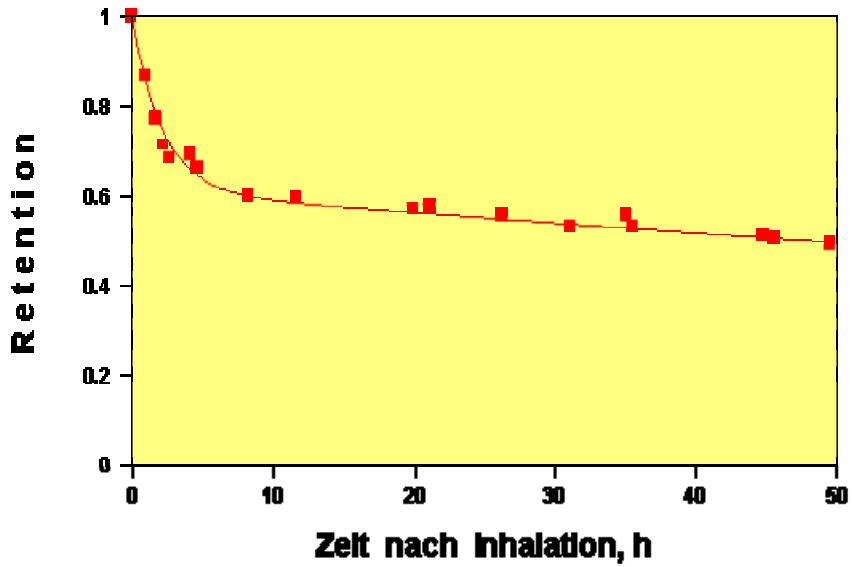
- 14 male and 14 female smokers switching from 13_1.2_16 mg (8 weeks) to 10_1.2_9 mg product (26 weeks), in compensation study (PMWNF_NIC_CO)
- 2 cigarettes smoked naturally in chamber in pairs; active in ~50% of visits; regional deposition on 3 visits
- Multiple measurements of tar, nicotine, cotinine, CO, DCO, smoking parameters, inhalation parameters
- Average Committed Effective Dose Equivalent (CEDE) of 3.4 mSv (cf WHO, g-camera studies)

Aged & Diluted SS

- 9 non-smoking male volunteers
- Smoke aerosol generated in 180 litre chamber (~ 0.86 $mg.m^{-3}$); sealed for thoron pulse; 15 minute decay period for ^{212}Pb
- Smoke diameter measured as 210 nm AMAD (Delron – GSD = 1.43) and 180 nm AMAD (QCM – GSD = 1.5)
- 6 minute controlled breathing with exhale capture
  - 6 x 1000 ml per min – nose
  - 6 x 1000 ml per min – mouth
  - 12 x 500 ml per min – mouth
- Average CEDE = 340 mSv

Differential Clearance

- Whole body counter
- Collimated NaI detectors
- Geometry : 1 x head, 2 x chest, 2 x stomach, 1 x leg
- Bronchial to pulmonary split by back-extrapolation of 2 curves
- Pulmonary behaviour limited by solubility of label
- No information on any slow bronchial clearance
- Regional deposition ±1% reproducible in individuals
- Dose of 1-5 Sv (deposition) to 50 Sv (regional deposition) - allows multiple administrations



Results – Aged & diluted SS

	Total	Head	Thorax	TB	P	t½ TB
6x1000 Nasal	61±10	6±2	55±11	14±5	41±7	8.3±3.3
LUDEP	33	0.7	32.2	6.5	25.7	
6x1000 Oral	43.1 ± 16.2	2.8 ± 1.2	40.5 ± 12.2	10.2 ± 3.8	30.3 ± 9.4	8.4 ± 2.2
LUDEP	33	0.6	32.4	6.6	25.7	
12x500 Oral	23±8	2±1	21±8	4±3	16±6	11.6 ± 2.8
LUDEP	20.5	0.6	19.9	6.0	14.0	

Aged SS data : deposition comparison

- Oral 6 x 1000 : 43.1 ± 16.2%

  *(Strong et al, Rad. Prot. Dos. **54** 47-56 (1994))*

- Oro-nasal 8 x 1000_60 min_MMAD 140 nm 41 ± 14

  *(McAughey et al, Inhalation Toxicology **6** 615-631 (1995))*

- Oral 410 nm MMAD 11 ± 4

  *(Hiller et al, Prev. Med. **13** 602-607 (1984))*

- Nasal 200 nm CMD 56.0 ± 15.9
- Oral 200 nm CMD 48.7 + 11.5

  *(Hofmann et al, J. Aerosol Med. **14** 317-326 (2001))*

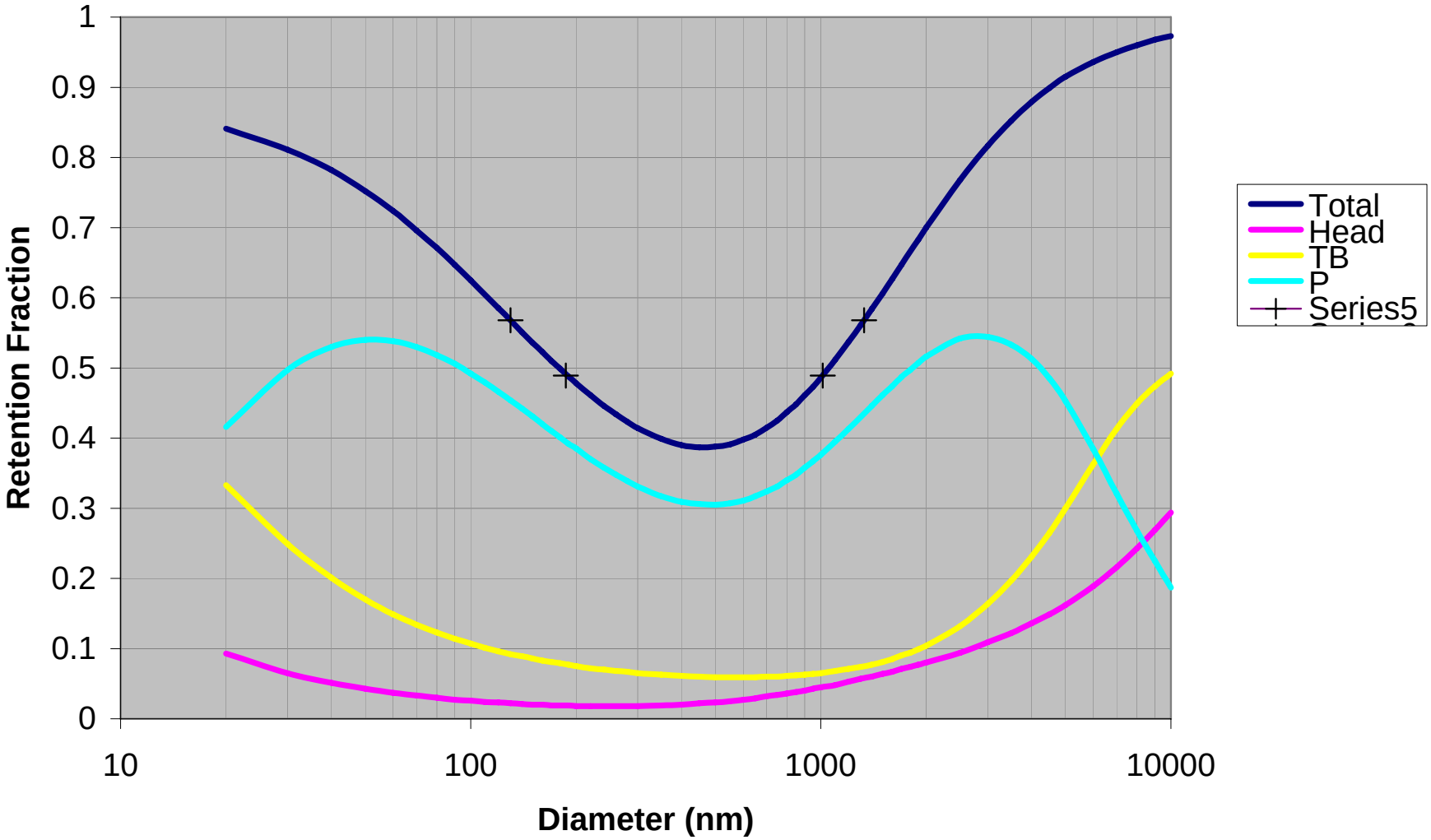
Mainstream smoking parameters

Marker	Male	Female
Puff Volume (ml) : 13 mg	58 ± 20	48 + 10
Puff Volume (ml) : 10 mg	70 ± 21	55 ± 10
Puff Duration (s) : 13 mg	2.0 ± 0.7	2.1 ± 0.6
Puff Duration (s) : 10 mg	1.9 ± 0.5	1.9 ± 0.4
Puff Flow (ml/s) : 13 mg	29.0 ± 3.7	24.1 ± 4.7
Puff Flow (ml/s) : 10 mg	35.5 ± 5.5	28.8 ± 5.1
Chest TPM (mg) : 13 mg	13.9 ± 4.6	12.4 ± 3.8
Chest TPM (mg) : 10 mg	14.0 ± 3.9	12.0 ± 3.9
Total TPM (mg) : 13 mg	14.7 + 4.5	13.9 + 3.1
Total TPM (mg) : 10 mg	14.8 + 3.7	14.1 + 3.3

Results – MS smoking (Head:TB:P ratios)

Marker		Male	Female
Head (%)	13 mg	5.4	10.8
	10 mg	5.4	14.9
P/(P+TB) (%)	13 mg	66.6 ± 7.9	60.0 ± 8.6
	10 mg A	65.9 ± 9.0	64.2 ± 12.1
	10 mg B	64.5 ± 5.9	68.2 ± 8.4
TB Half-life (h)	13 mg	1.4 ± 0.7	2.3 ± 1.6
	10 mg A	2.2 ± 0.9	1.7 ± 1.0
	10 mg B	1.8 ± 0.9	1.6 ± 0.7
P Half-life (h)	13 mg	15.9 ± 1.6	24.5 ± 19.0
	10 mg A	17.1 ± 2.6	18.0 ± 2.7
	10 mg B	17.8 ± 2.2	17.4 ± 3.1

Retention curve, MPPD Dosimetry Model



Summary

- Low-dose radiotracers combined with a g-detection array have been used to determine regional deposition patterns of mainstream and aged & diluted sidestream smoke (ETS)
- Exhale capture for ETS has also yielded absolute retention data
- Retention is generally greater than model predictions
- The pattern of thoracic regional deposition of is such that most mass is delivered to the pulmonary region
  - 60 – 68% for MS
  - 75 – 76% for ETS
- However, highest mass per unit area will occur in TB region
- Deposition patterns are consistent with small (sub-micron) particle deposition

Acknowledgements

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  - ETS : Center for Indoor Air Research (^{212}Pb)
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