

Review of Proposed Technique for Unionized Nicotine in Mainstream Cigarette Smoke

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Outline of Presentation

- **Background**
- **Review of proposed technique**
 - Experimental
 - Calculations
- **Practical issues with proposed technique**
- **Theoretical issues with proposed technique**
- **Acids and bases in mainstream smoke**
- **Conclusions**



Background

- **Proposed regulation (660.104) calls for the reporting of unionized nicotine in smoke**
- **Proposed regulation [660.200 (D)] specifies technique described in recent article by J. F. Pankow, *Chem. Res. Toxicol.* 2003, 16, pp. 1014-1018**
- **Pankow's technique reportedly measures unionized nicotine in the mainstream particulate matter (PM, a/k/a TPM)**



Steps in Proposed Technique (1)

- 1. Use Massachusetts vent-blocking and puffing conditions**
- 2. Collect first 3 or remaining (about 8) puffs into separate Teflon bags**
- 3. Wait about 15 minutes**
- 4. Sample aerosol in bag and pass sample through particulate filter**
- 5. Effluent from particulate filter goes into Tenax-TA trap**

Steps in Proposed Technique (2)

6. Determine PM and nicotine on filter and nicotine on trap (c_p , c_{g1})
7. Add ammonia gas to the smoke aerosols in the bags
8. Resample aerosol in bag and pass sample through particulate filter
9. Effluent from particulate filter goes into Tenax-TA trap
10. Determine PM and nicotine on filter and nicotine on trap (c_p , c_{g2})

Definitions Used in Proposed Technique (1)

- c_p = concentration of nicotine in PM filtered from aerosol sample
 - Values should be similar to concentration of nicotine in TPM from 600.200 (C)
- $c_{g,1}$ = concentration of nicotine in gas stream after filtration of PM
- $c_{g,2}$ = concentration of nicotine in gas stream after filtration of PM with added ammonia
- α_{fb} = fraction of nicotine that is unionized

Definitions Used in Proposed Technique (2)

- $K_p = c_p/c_g$ = gas-particle partitioning coefficient for nicotine in smoke
 - Assumes equilibrium for the partitioning of nicotine between the gas phase and particulate phase of the smoke aerosol
- $K_{p,fb}$ = gas-particle partitioning coefficient for nicotine in smoke when there is no ionized nicotine present
- $pK_a = 8.06$ = disassociation constant for nicotine in water at 20° C
- pH_{eff} = calculated smoke pH

Calculations Used in Proposed Technique

- $(c_p/c_{g,2})/(c_p/c_{g,1}) = K_{p,fb}/K_p$
- $K_{p,fb}/K_p = \alpha_{fb}$
- $\text{pH}_{\text{eff}} = \text{p}K_a + \log [\alpha_{fb}/(1 - \alpha_{fb})]$

Practical Issues with Proposed Technique (1)

- **It does not provide the requested data**
 - Technique purports to provide concentration of unionized nicotine in PM
 - Technique does not give level of unionized nicotine in smoke
- **It is a research *technique*, NOT a *validated method***
 - Has not been validated for range of products
 - Has not been validated using equipment and conditions in cigarette testing laboratories

Practical Issues with Proposed Technique (2)

- **There has not been an interlaboratory study to determine repeatability and reproducibility of the results**
 - Can the results be repeated at different times in the same laboratory?
 - Are the results reproducible from one laboratory to another?

Practical Issues with Proposed Technique (3)

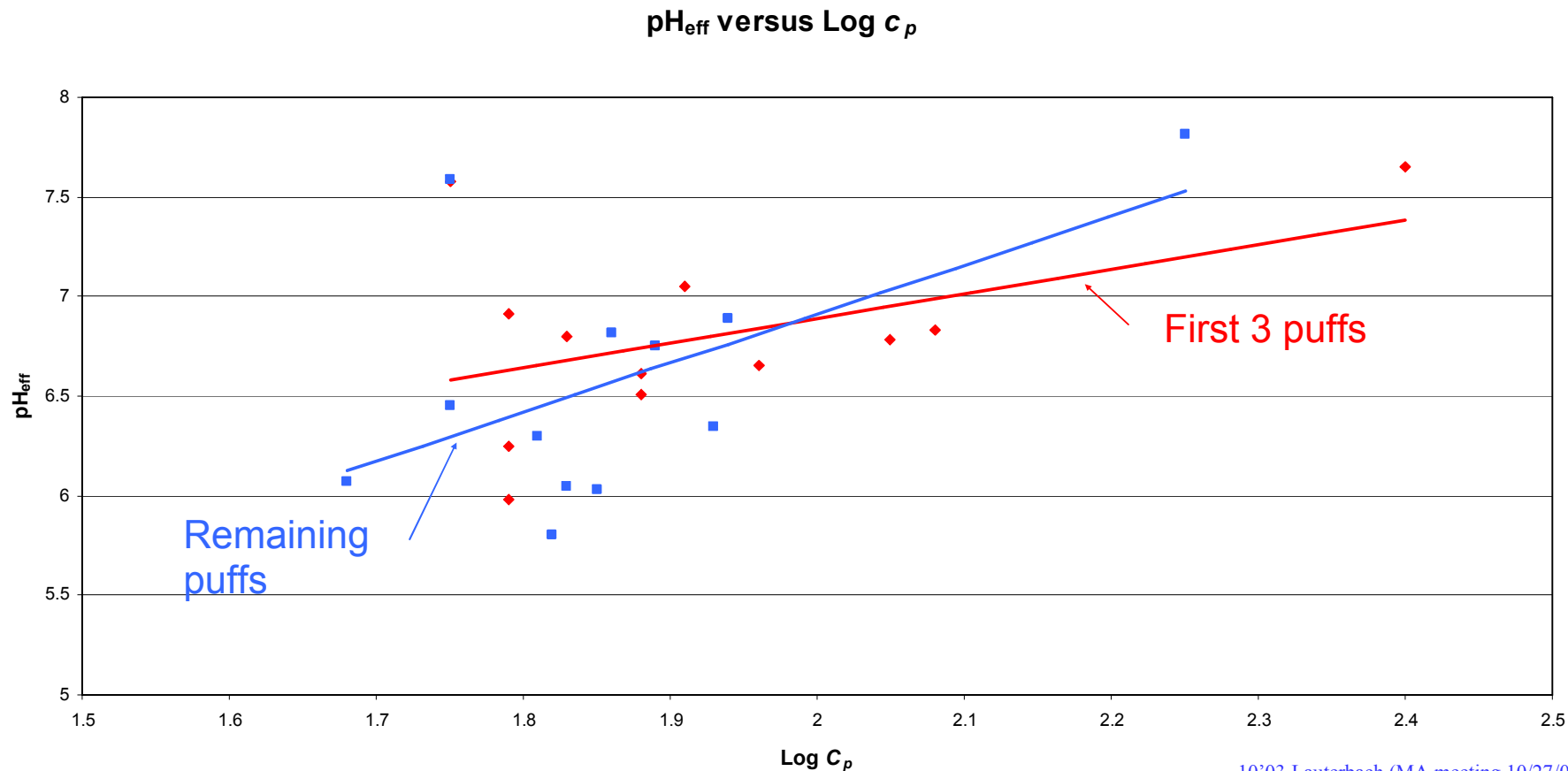
- **Non-standard conditions and equipment**
 - Cigarettes not conditioned prior to smoking
 - Cigarettes not smoked to standard butt length [the specified butt length (23 mm) would involve smoking into the tipping and filter for many products]
 - Equipment used for smoke generation and collection not proven (e.g., did Zeofluor membrane retain all particulate matter?)

Practical Issues with Proposed Technique (4)

- **Technique gives anomalous results**
 - Predominately flue-cured cigarettes known to give acidic smoke
 - Predominately burley or dark air-cured cigarettes known to give basic smoke
 - US blended cigarettes fall in between
 - GPC 100s, a blended product containing DAP gave much lower pH_{eff} than did American Sprit, a predominately flue-cured cigarette without additives

Theoretical Issues with Pankow's Technique (1)

- pH_{eff} appears to be correlated with c_p , the concentration of nicotine in PM
- Is this a problem with the technique?



Theoretical Issues with Pankow's Technique (2)

- **In addition to protonated nicotine, smoke contains numerous other acids and compounds that can react with ammonia**
 - Carbonic acid (from carbon dioxide and water produced from combustion of the tobacco)
 - Various organic acids
 - Numerous carbonyl compounds
- **Hold time (~15 minutes) between smoke collection and separation of particulate matter allows for reactions of ammonia**

Theoretical Issues with Pankow's Technique (3)

- **Major acids in mainstream cigarette smoke**
 - Protonated nicotine
 - Carbonic acid from reaction of carbon dioxide and water ($\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3$)
 - Total smoke water (gas-phase and particulate-phase) 2X to 10X amount of particulate-phase water
- **Is the amount of ammonia added by Pankow sufficient to neutralize acids?**

Acids and Bases in Mainstream Smoke (1)

	Virginia	Burley	Turkish	Blended
Puff count	15.5	10.5	18.1	8.4
“Tar” (µg/cig)	16430	12495	12670	11256
Nicotine (µg/cig)	2155	2153	833	941
TPM (µg/cig)	20150	15960	14480	13894
CO ₂ (µg/cig)	50189	47397	51893	39698
NH ₃ (µg/cig)	15.5	126	32.9	16.0

Data adapted from B. J. Ingebrethsen et al., *Aerosol Sci. Technol.* 2001, 35, pp. 874-886

Acids and Bases in Mainstream Smoke (2)

	Virginia	Burley	Turkish	Blended
Puff count	15.5	10.5	18.1	8.4
Nicotine (µg/cig)	2155	2153	833	941
Nicotine (µmol/cig)	13.3	13.3	5.14	5.81
CO₂ (µg/cig)	50189	47397	51893	39698
CO₂ (µmol/cig)	1141	1077	1179	902
NH₃ (µg/cig)	15.5	126	32.9	16.0
NH₃ (µmol/cig)	0.912	7.41	1.94	0.944
Added NH3 (µg/cig)	4900	4900	4900	4900
Added NH3 (µmol/cig)	83.3	83.3	83.3	83.3

Data adapted from B. J. Ingebrethsen et al., *Aerosol Sci. Technol.* 2001, 35, pp. 874-886; and J. F. Pankow et al., *Chem. Res. Toxicol.* 2003, 16, pp. 1014-1018

Conclusions on Pankow's Technique (1)

- **Insufficient ammonia added to neutralize smoke acids**
 - Invalidates underlying scientific basis for the technique
 - Adding more ammonia not satisfactory as amount needed to neutralize all acids would require detailed knowledge of each product's smoke chemistry
- **Hold time of ~ 15 minutes allows for chemical and physical changes to occur**

Conclusions on Pankow's Technique (2)

- **It should not serve as a basis for regulation**
 - Not scientifically valid
 - Not a method that has been validated through proper scientific study
- **It does not provide the level of unionized nicotine in smoke as specified in the proposed regulations**