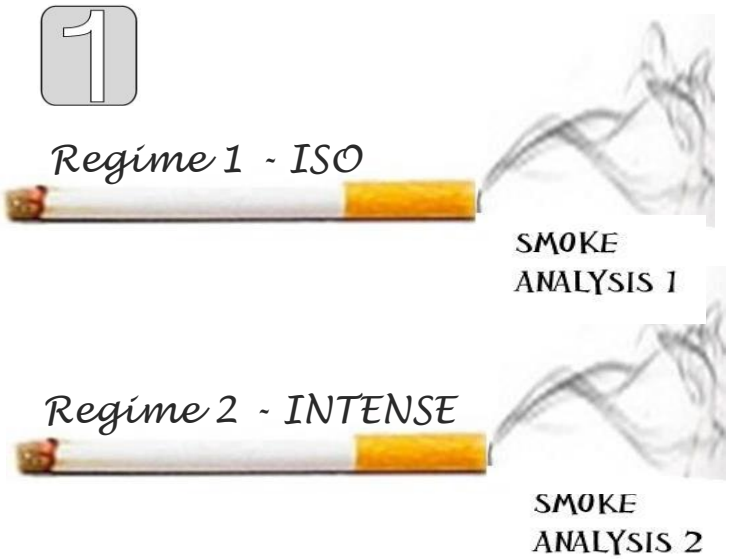
Optimisation of testing scheme by associating smoking data with cigarette burning model

Stéphane COLARD

What is the question?



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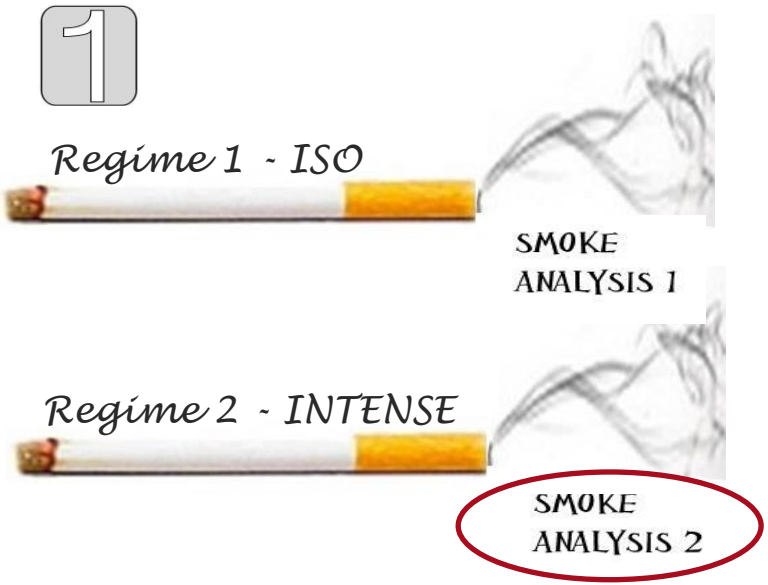

- Variability issues observed with intense regimes
- Testing cost x2

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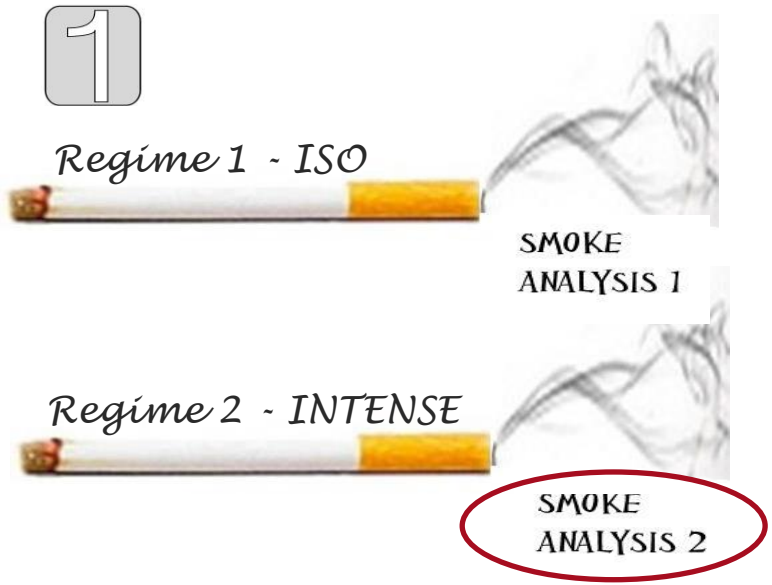

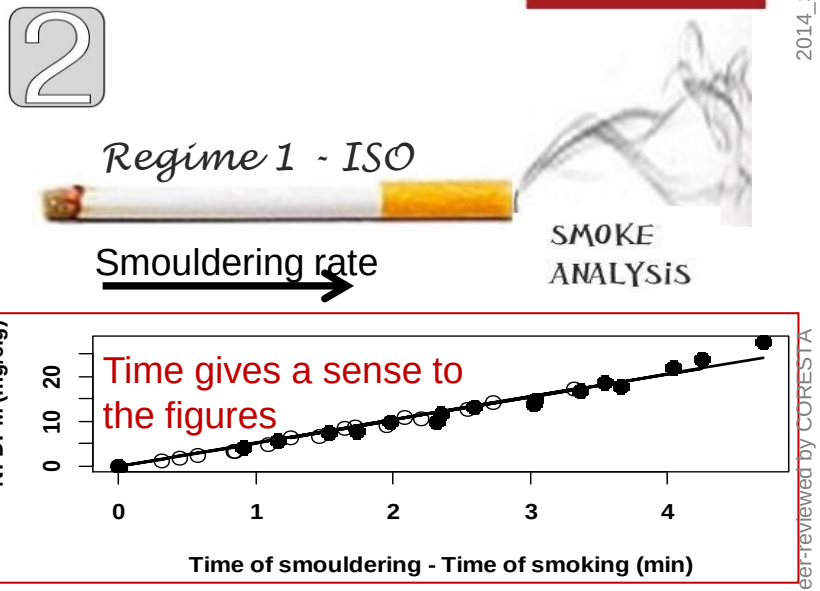

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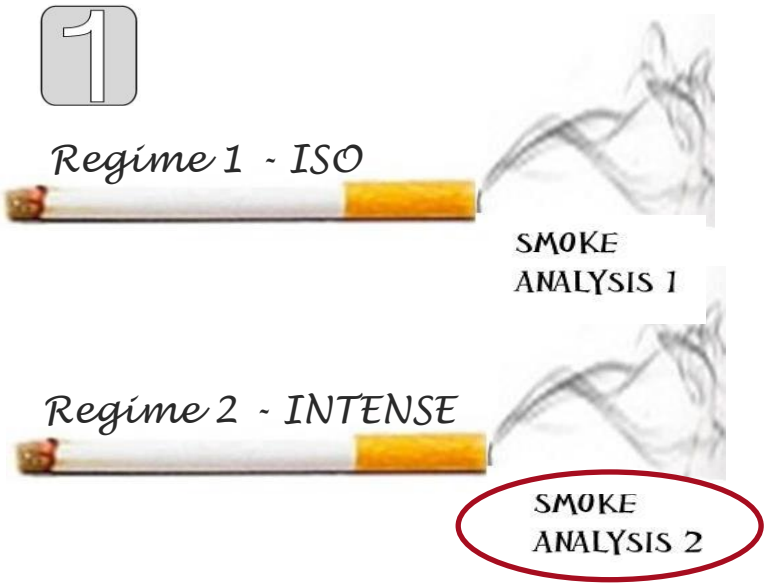

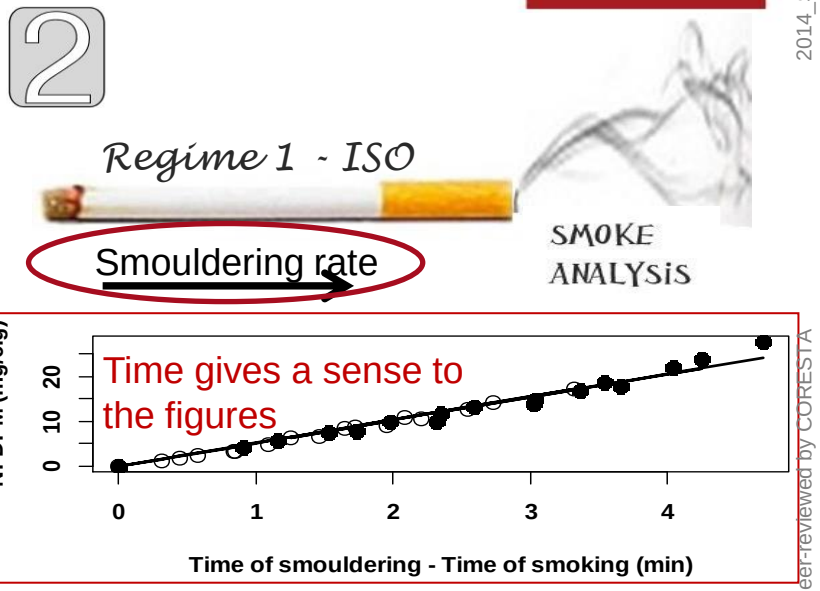

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- Possible smouldering rate (SR) measurement difficulties with LIP products
- Cost of SR measurement

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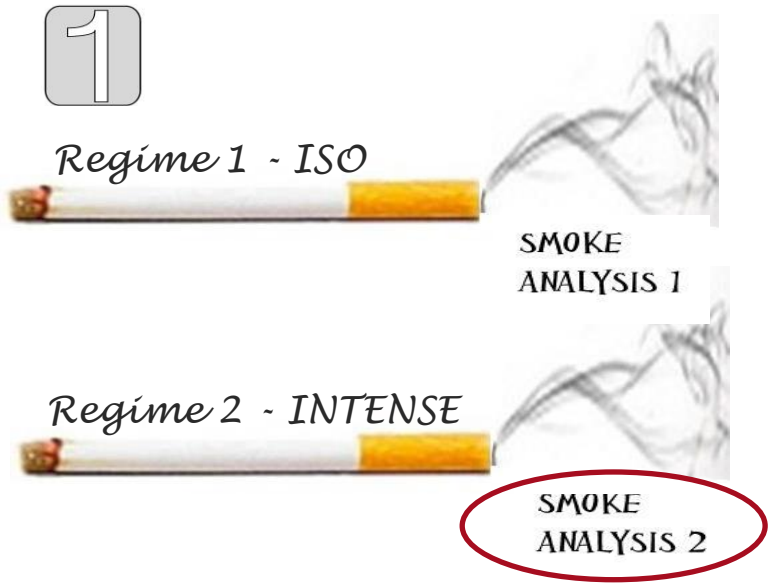

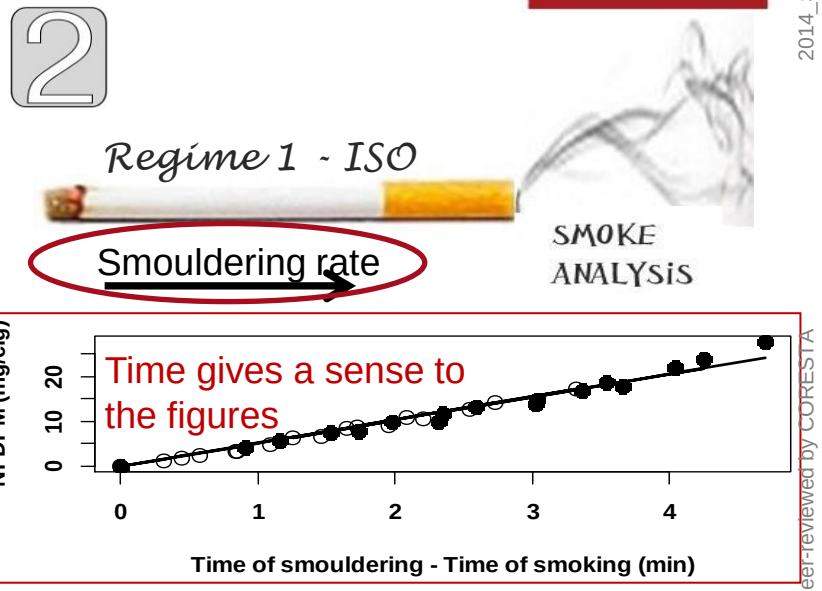

- Variability issues observed with intense regimes
- Testing cost x2

Could we overcome these limitations?

- Possible smouldering rate (SR) measurement difficulties with LIP products
- Cost of SR measurement

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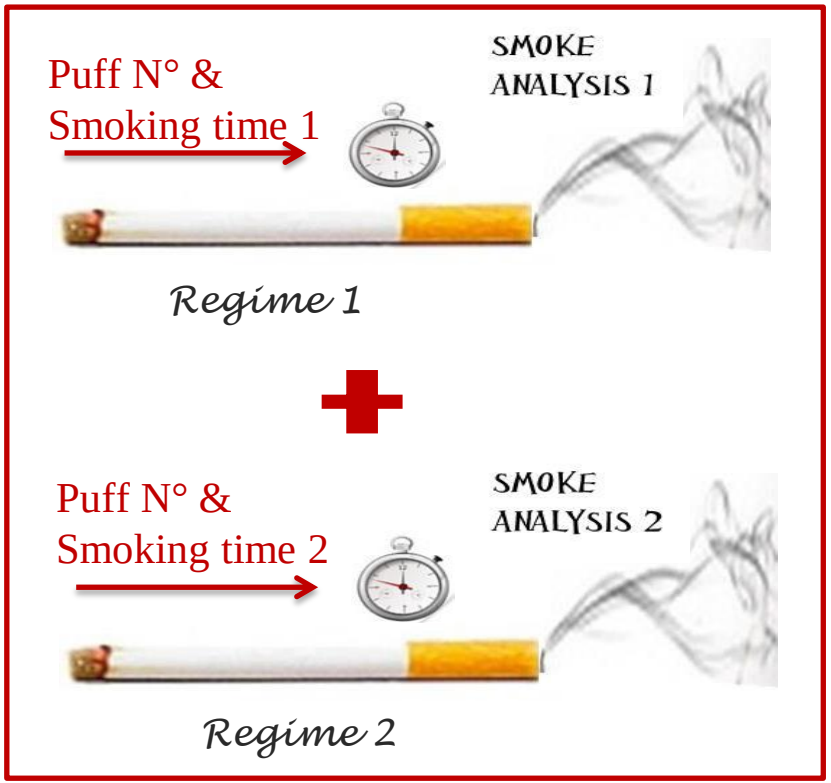
Investigations on Possible Alternative Approach



Note: The smoking time can either be measured or estimated from the number of puffs

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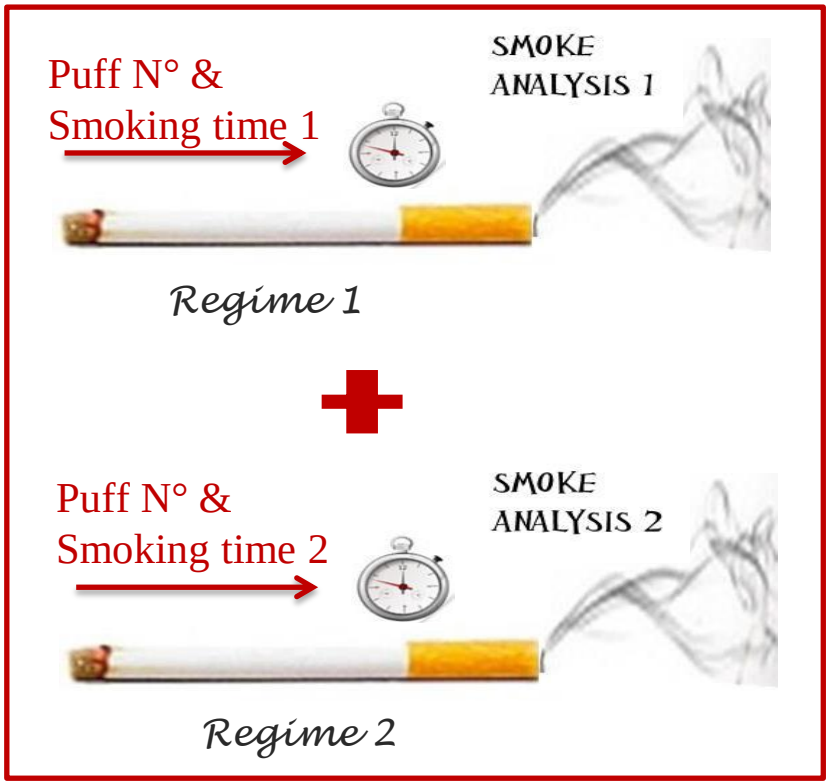

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Cigarette Burning Model

Let's see what it tells us?

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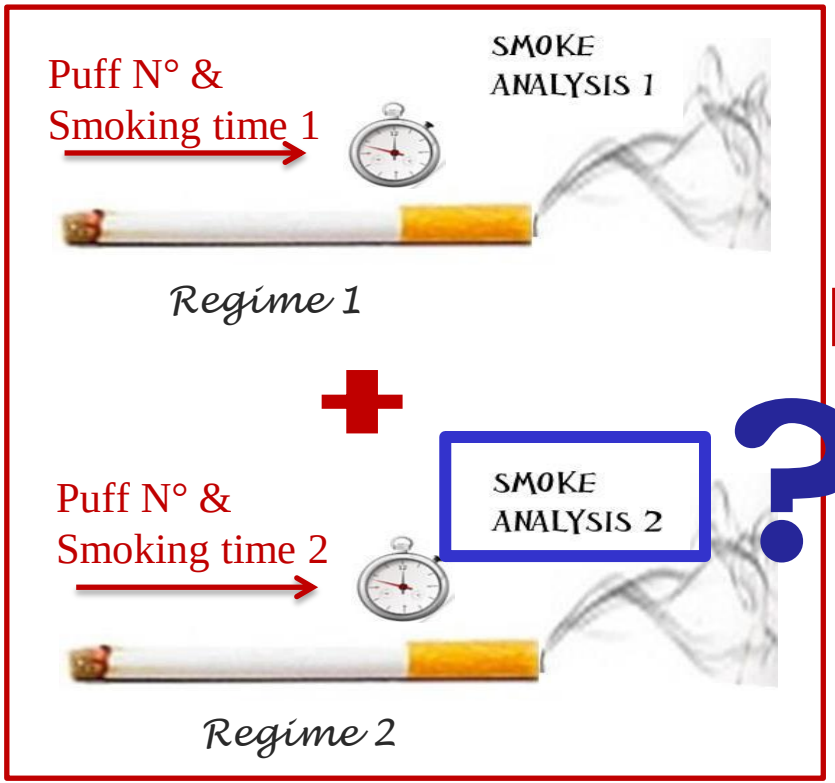

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Cigarette Burning Model

Let's see what it tells us?

Is a second regime of added value?

Approach Model/Data/Derivation

1 Cigarette paper air permeability

$$Q = \omega \times S \times \Delta P$$

Measurement of ΔP
Measurement of Q

Determination of ω

2 Chemical reaction kinetics

$aA+bB \rightarrow cC + dD$

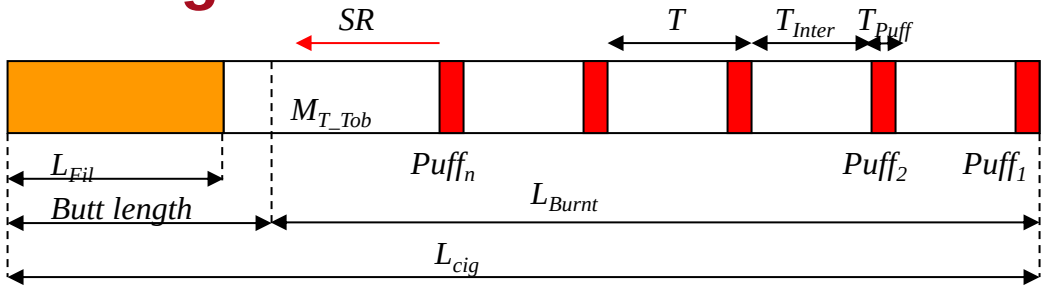
$$Rate = -\frac{1}{a}\frac{\Delta[A]}{\Delta t}$$

Measurement of [A] vs t

Determination of the reaction rate

Order	Straight Line Plot	Integrated rate law	Rate
0	[A] vs t	$[A]=-k.t+[A]_0$	Rate=k
1	ln[A] vs t	$\ln[A]=-k.T+\ln[A]_0$	Rate=k.[A]
2	1/[A] vs t	$1/[A]=2k.t+1/[A]_0$	$Rate=k.[A]^2$

Cigarette burning model



$$L_{Burnt} = a \times k \times \overline{SR} + b \times \overline{SR}$$

During puffs

Between puffs

The factors *a* and *b* are easily calculated from the number of puffs, the puff volume, the puff duration and frequency, the filter ventilation and the smoking time

If the puff number is not an integer,

$$a = N_{Puff} \times V_{Puff} \times (1 - FV)$$

$$b = Int(N_{Puff}) \times T_{Inter}$$

If the puff number is an integer,

$$a = N_{Puff} \times V_{Puff} \times (1 - FV)$$

$$b = (N_{Puff} - 1) \times T_{Inter} + \left[T_{Smoking} - (N_{Puff} - 1) \times (T_{Puff} + T_{Inter})\right]$$

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What the testing scheme tells us?

The application of two regimes provides simultaneous equations

$$L_{Burnt} = a_1 \times k \times \overline{SR} + b_1 \times \overline{SR}$$
$$L_{Burnt} = a_2 \times k \times \overline{SR} + b_2 \times \overline{SR}$$

The mean smouldering rate between puffs from the recording of puff numbers and smoking times with 2 regimes

$$\overline{SR} = \frac{a_1 - a_2}{a_1 \times b_2 - a_2 \times b_1} \times L_{Burnt}$$

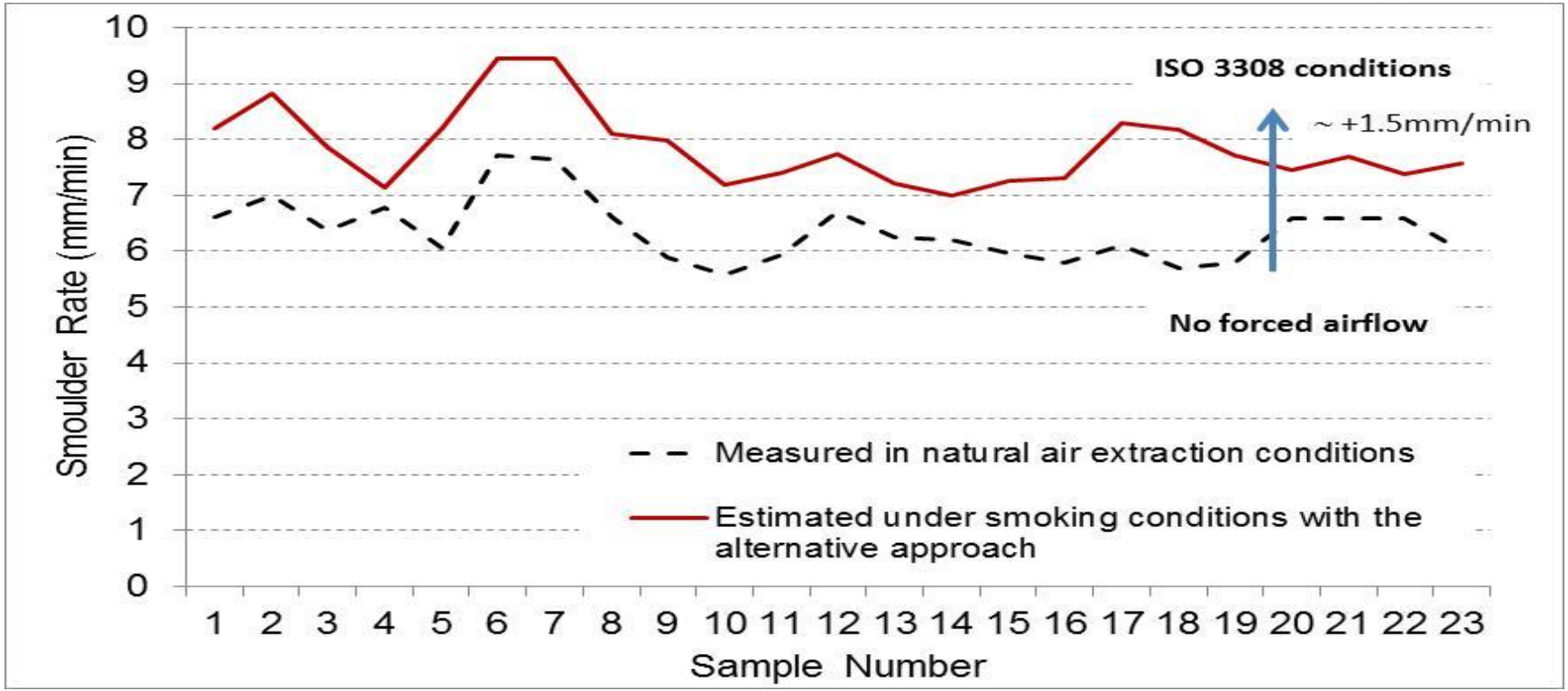
1: smoking regime 1
2: smoking regime 2

… and so, the smouldering time

The factor *k* relating coal airflow and length (or weight) burnt

$$k = \frac{b_2 - b_1}{a_1 - a_2}$$

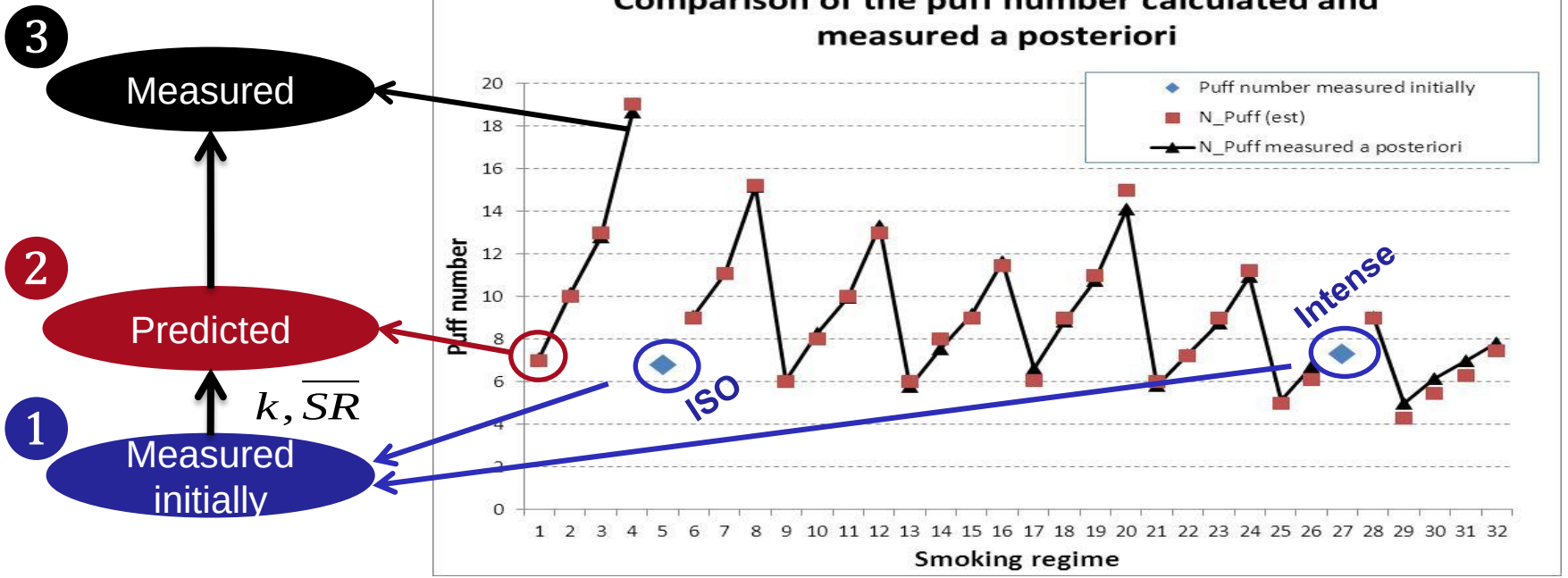
Smouldering rate estimate



All 23 samples tested were LIP designed commercial products with different papers, diameters and blends

Number of puffs

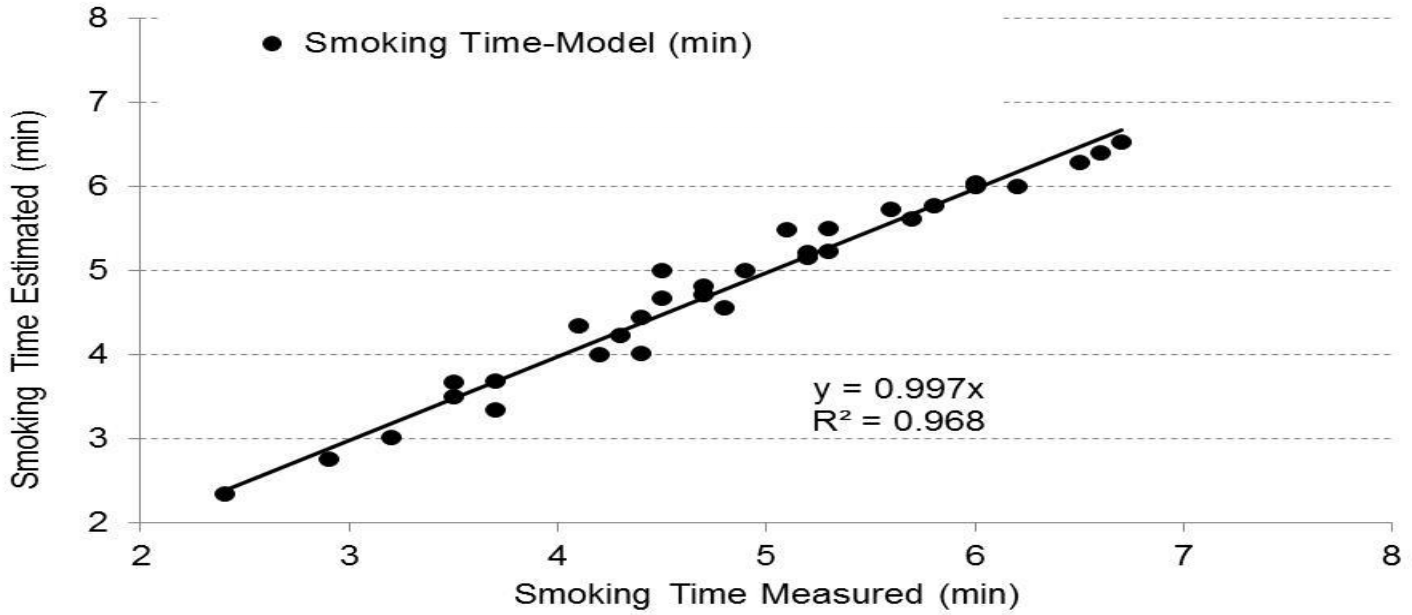
The parameters derived from two smoking conditions and the model enable the calculation of the number of puffs whatever the smoking regime applied



Smoking regimes - Puff frequency : 20s, 30s, 40s and 60s. Puff volume : 17.5ml, 35ml, 55ml, 70ml. Filter ventilation: open & blocked

Smoking Time

The parameters derived from two smoking conditions and the model enable the calculation of the smoking time whatever the smoking regime applied



Smoking regimes - Puff frequency: 20s, 30s, 40s and 60s. Puff volume : 17.5ml, 35ml, 55ml, 70ml. Filter ventilation: open & blocked

Weight actively burnt

The parameters derived from two smoking conditions and the model enable the calculation of the weight actively burnt during puffing whatever the smoking regime applied

$$L_{Activeburnt} = L_{Burnt} - \left(ST - N_{Puff} \times T_{Puff}\right) \times \overline{SR}$$

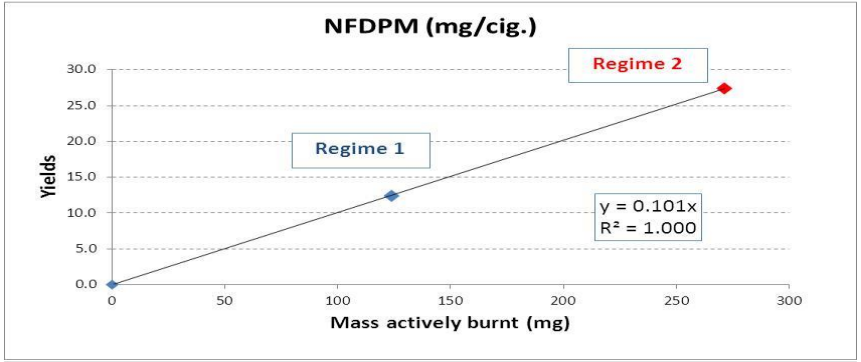
Length burnt between puffs

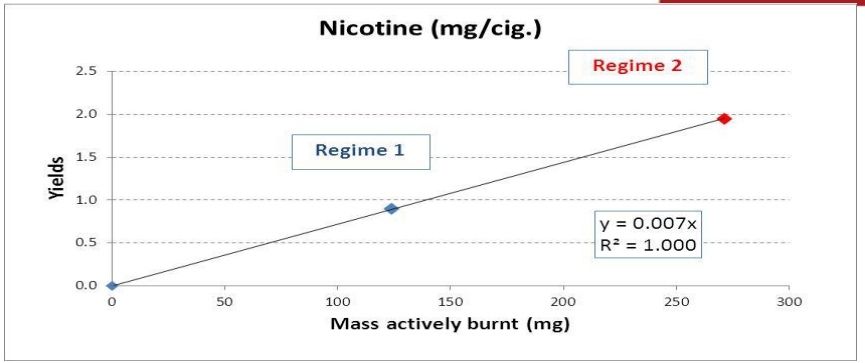
$$M_{Activeburnt} = \frac{L_{Activeburnt}}{L_{Cig} - L_{Fil}} \times M_{T\_Tob}$$

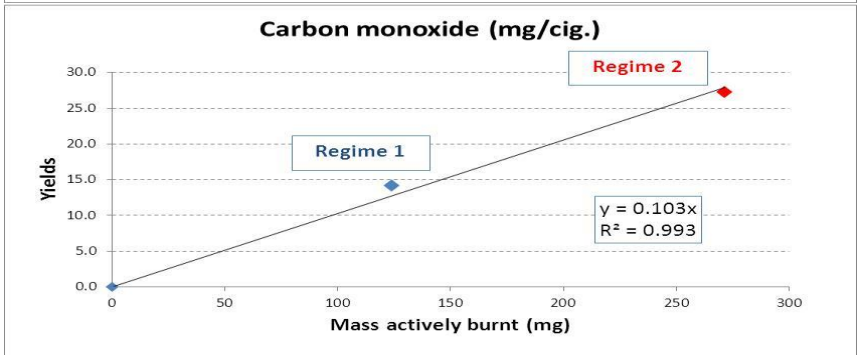
The mass actively burnt (during puffs) can be calculated irrespective of which smoking regime is used

ST: Smoking Time; T_{Puff}: Puff duration; M_{T_Tob}: Mass of tobacco

Weight actively burnt and yields





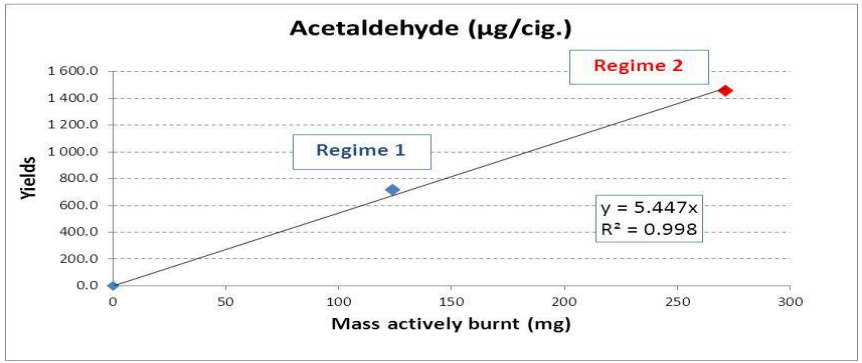


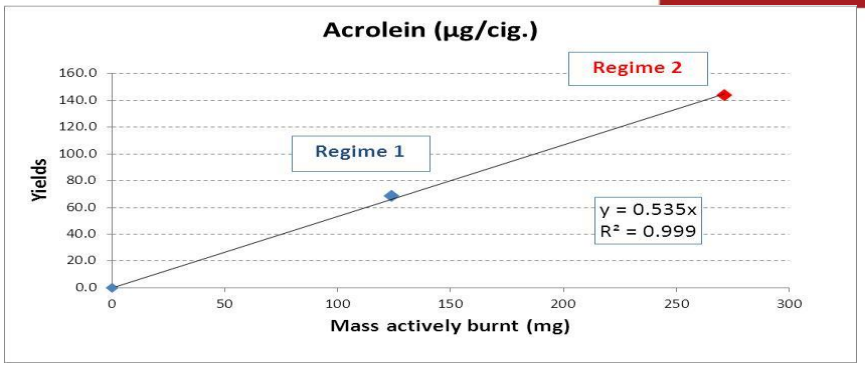
Regime 1: ISO (vent open)
Regime 2: Intense (vent blocked)

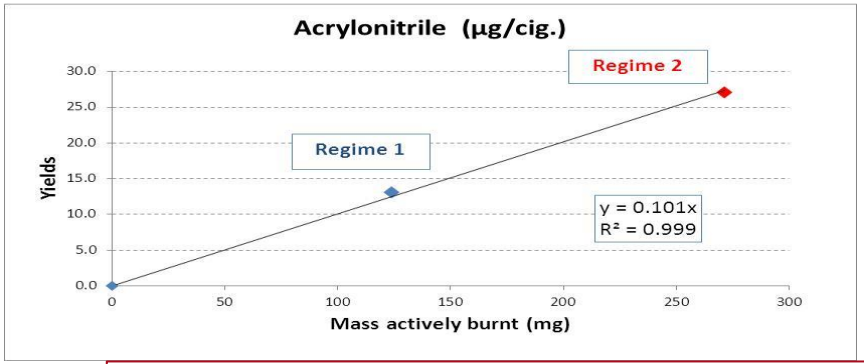
Since the mass actively burnt can be calculated irrespective of which smoking regime is used, yield figures generated from an additional regime don't seem to provide useful additional information.

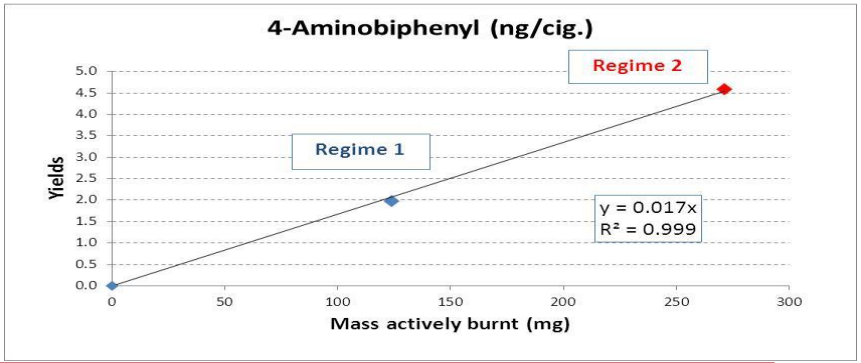
What about other smoke constituents?

Yields vs mass tobacco burnt









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Similar observations over a range of cigarette formats with acetate filters

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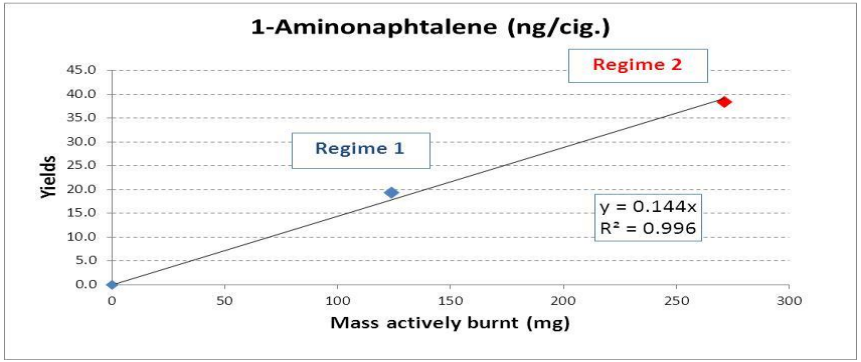

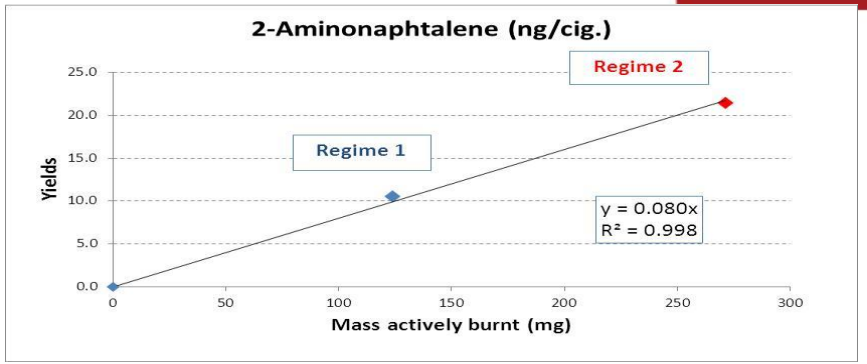

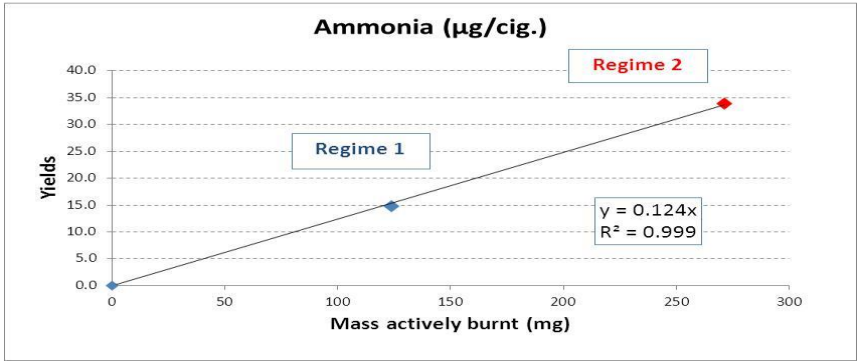

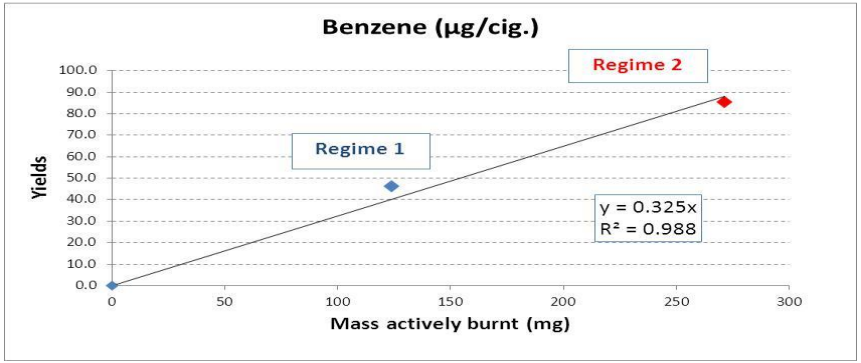

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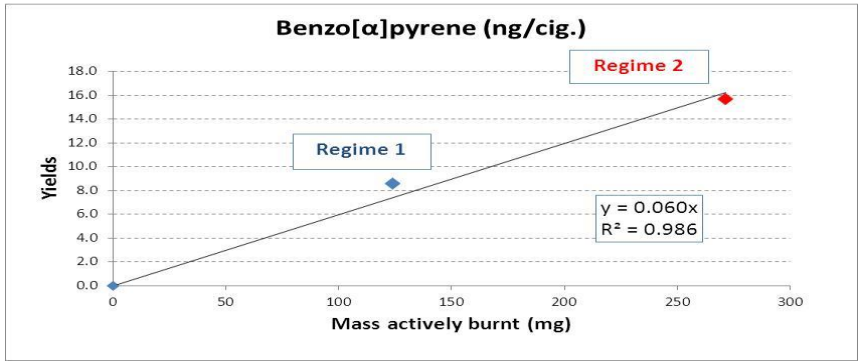

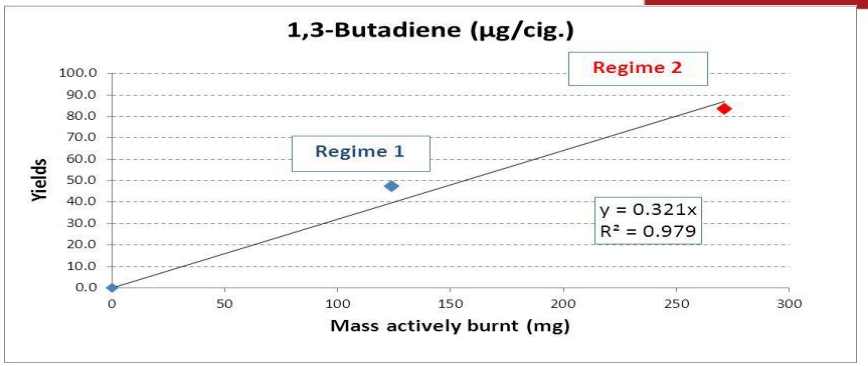

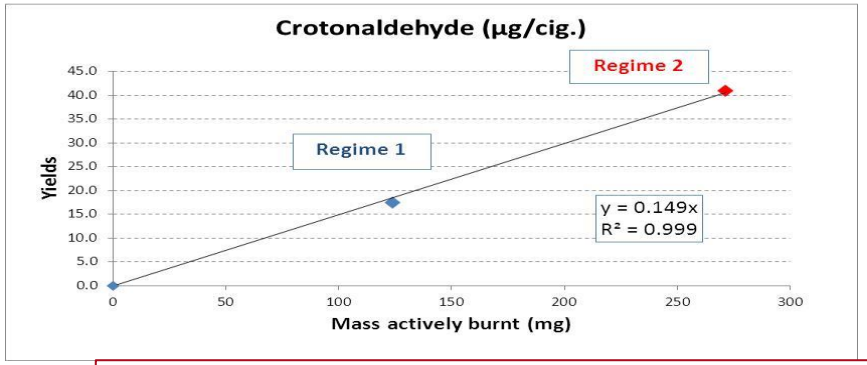

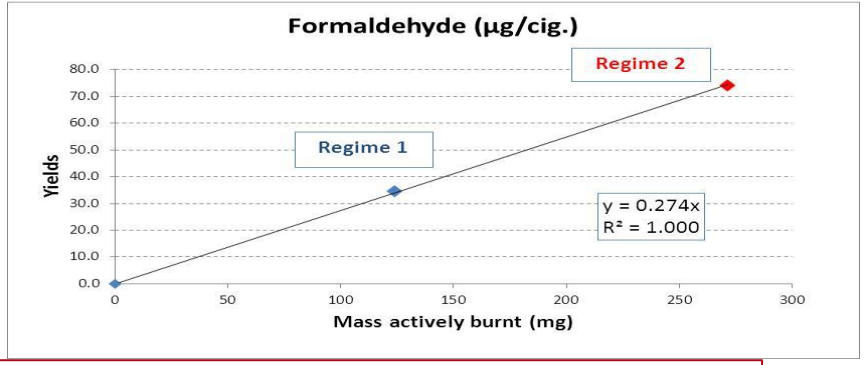

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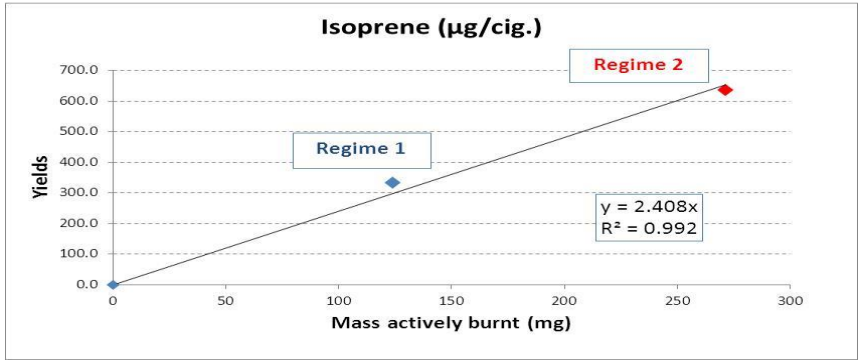

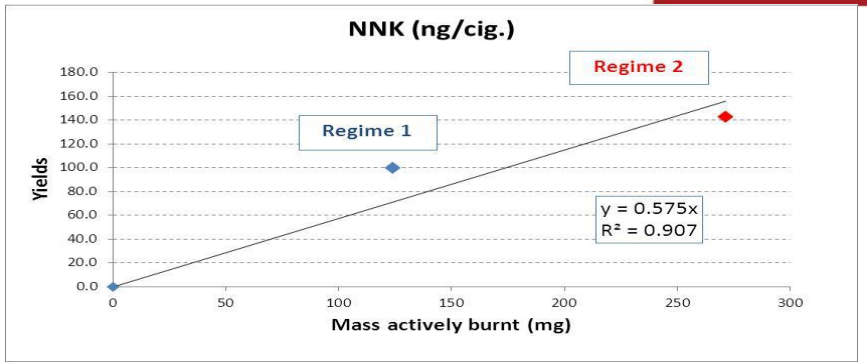

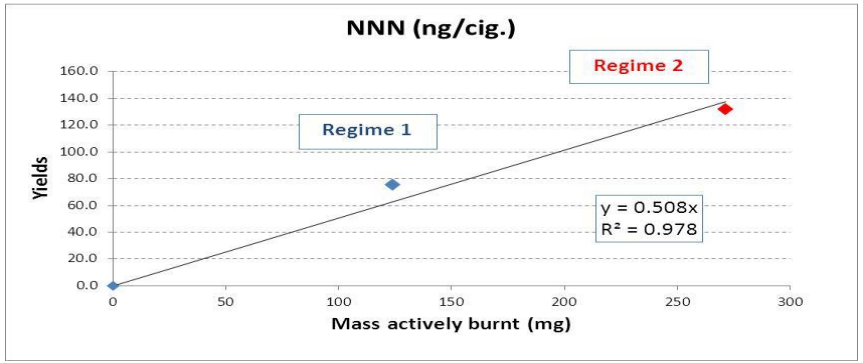

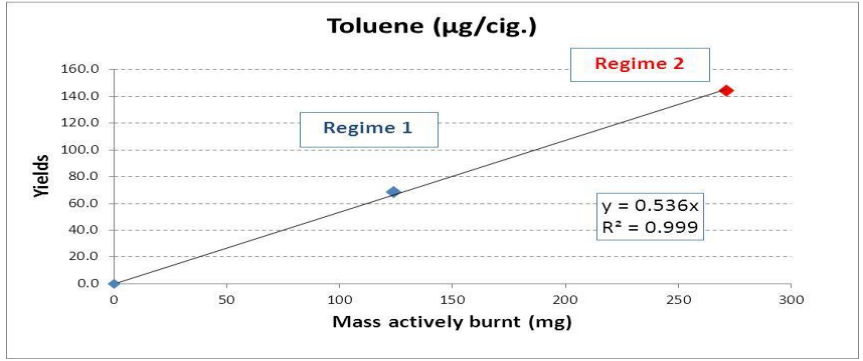

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Similar observations over a range of cigarette formats with acetate filters

What else?

- Emission rate

$$EmR = \frac{Yield}{M_{Activeburnt}}$$

➡ Core product characteristic

- Puffing transfer rate

$$Tr_{Puff} = \frac{Yield}{M_{Activeburnt} \times [BlendConstituent]}$$

➡ Transfer studies
Pyro synthesis studies
Comparison of blends
Comparison of filters

- Puffing burnt rate

$$Puff_{BurntRate} \frac{M_{Activeburnt}}{N_{Puff} \times \overline{V_{Coal}}}$$

➡ Comparison of design

Can We Arrive at an Optimised Testing Scheme?

YES

Puff N° &
Smoking time 1

Regime 1

+

Puff N° &
Smoking time 2

Regime 2

What does-it tell us?

- Smouldering rate
- Puffing burnt rate
- Puffing transfer rate
- Emission rate

Whatever the smoking regime applied:

- Weight burnt during puffs
- Number of puffs
- Smoking time

Conclusions

- **A testing scheme incorporating a burning model overcomes:**
  - The smouldering rate measurement issue with LIP products, and reduces the testing time
  - The smoke trapping issue/variability which may occur with a second regime and the corresponding testing burden
- **And**
  - Leads to a comprehensive characterisation of the product under different regimes

- **Our experiments show that yields are proportional to the mass of tobacco burnt during active puffing for a given product**
  - This mass can be calculated from the proposed approach, irrespective of which smoking regime applied – Double yields analysis is not of added value.

Thank you for your attention

Acknowledgments to the Lab technicians who produced the analytical figures

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