The Desorption Effects on Puffing on CFH Condensate

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Introduction

Comparing yield data for e-cigarettes or conventional cigarettes is a routine task for most analytical smoking laboratories. In most cases the inherent variability of the products under test mask any systematic failings of the experimental methodology.
However testing under different puffing regimes for conventional cigarettes and the various new methods being applied to e-cigarettes and THP products necessitate a review of some potential sources of systematic experimental methodology.

An example is the impact of repeated puffing on a Cambridge Filter Pad that may have a high water or humectant loading as might be occur when testing e-cigarettes or THP products. There may be desorption effects that reduce the total captured material.

These might be small for a limited number of puffs in a ENDS (Electronic Nicotine Delivery System) puff block but much greater for an extended experiment where a pad might become saturated as might be achieved with a full life ENDS test or when using a rotary machine for smoking THP's (Tobacco Heating Product) [1].

Experimental

A model "TPM" (Total Particulate Matter) equivalent as might be generated from a THP is available in the literature [2] that consists of a mixture of Propylene Glycol (PG), Vegetable Glycerol (VG) and water in the ratio 1.7:45:53.

Conditioned Cambridge filter pads (44mm) were loaded into their holders, capped and weighed, and then precise loadings of the mixture added with a micropipette. The holders were capped, allowed to equilibrate for 24hrs and then weighed for a baseline reference value. The holders were then puffed using a Cerulean linear smoking machine in fixed puff mode with a monocetate filter rod in place with the same pressure drop as a conventional cigarette.
The puffing scheme is shown in table 1.

	Puff volume	Puff duration	Puff interval	Puff shape	Target Loading
Run Ex1	35ml	2s	60s	ISO Bell	85 µL
Run Ex2	55ml	2s	30s	ISO Bell	130 µL
Run Ex3	35ml	2s	30s	ISO Bell	85 µL
Run Ex4	20ml	2s	30s	ISO Bell	130 µL
Run Ex5	65ml	2s	30s	ISO Bell	130 µL

Table 1: Parameters for desorption experiments Linear smoking machine

The puffing scheme was devised to build a picture of any loss caused by successive puffs and also the influence of puff volume on this loss.

Holders were removed and weighed periodically to build a picture of change in weight from the action of puffing alone.

The percentage loss for the various regimes are shown in figure 1. It can clearly be seen that increasing the puff volume increases the proportionate loss of the mixture on the pads. It should be recognised that changing puff volume for constant puff duration also increases the flow rate of air through the pad.

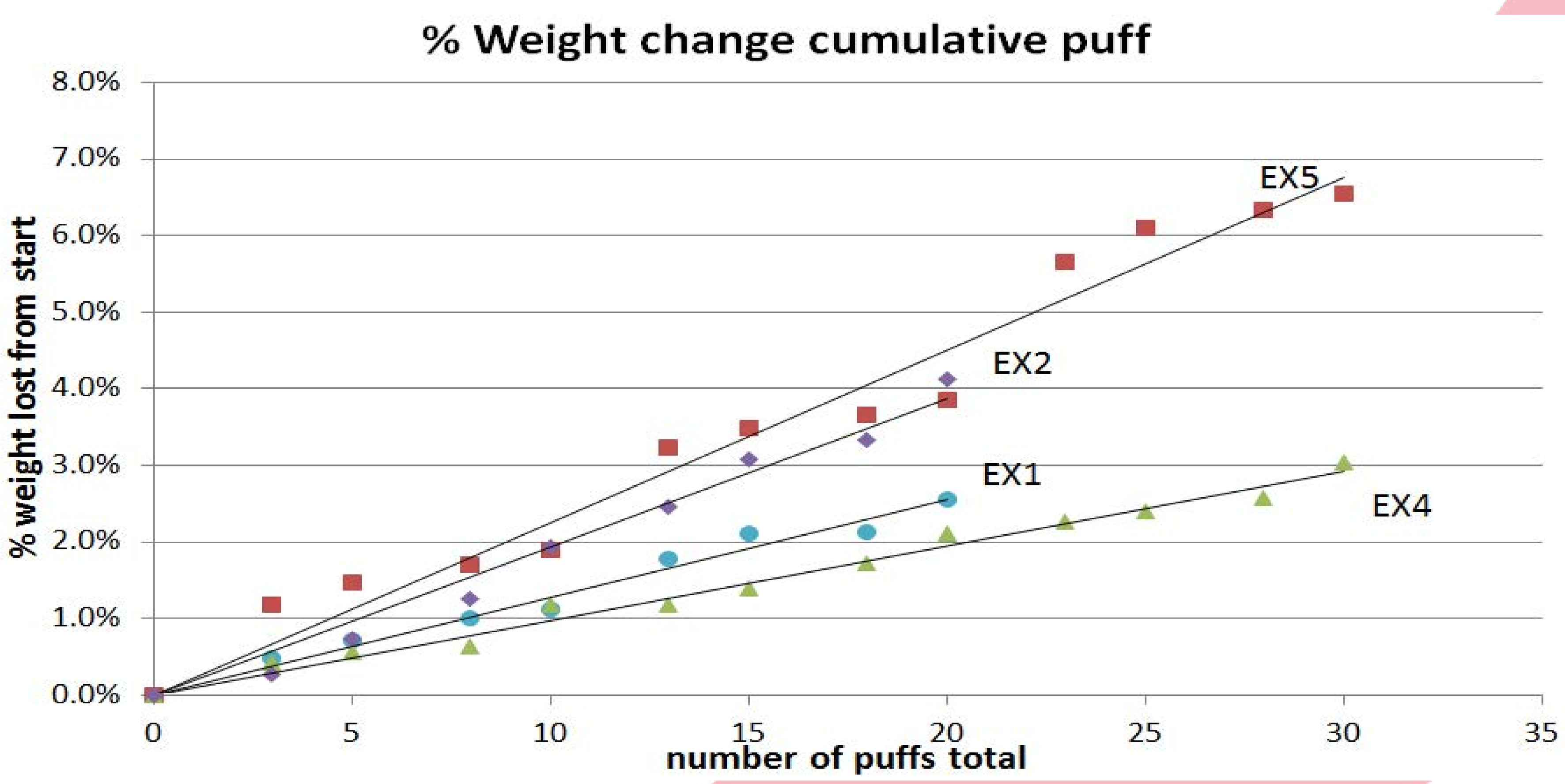

Figure 1: Plot of % weight loss of model compound with puff number for various puff volumes

1]Borgerding, Milhous, Hicks, Glass "Cigarette smoke composition. Part 2 Method for determining major components in smoke of cigarettes that heat not burn". J.Assoc.Off.Anal. Chem.73 1990
[2]Rickert, Wright." Yields of selected mainstream constituents in relation to smoking regime and smoking machine type" 60th TSRC Montreal 2006

Each proportionate loss can be approximated by a linear curve for the early stages of puffing . This tends to become increasingly non linear as the puff cycles increase and it is presumed eventually reaches an asymptote.

The interval between puffs do not influence the percentage loss of material in this model.

If considered as linear and the slope plotted against puff volume an approximation can be made for the loss of TPM based on only puff volume and puff number.

It should be possible from this data to prepare an equation that describes as a function of puff volume and puff number the apparent measured yield from a cigarette as a function of the true yield before any desorption has taken place.

$$Y_o = \frac{Y_m}{(1 - \sum_1^N f(x))}$$

Y_o = original yield of TPM if no puffing had occurred
Y_m = measured yield of TPM,
N = total number of puffs
f(x) = function of %loss related to the puff volume

And

$$Y_M = Y_O \left((1 - 4.10^{-5}VN) + (1 - 4.10^{-5}V(N - B)) + \cdots (1 - 4.10^{-5}V(N - SB))\right)$$

Where

Y_O = per cigarette yield before puffing loss
Y_M = measured yield of TPM,
N = total number of puffs
B = Per cigarette puff number
V= puff volume
S = number of puffs per channel

Using this equation an experiment was performed where a single rod was smoked onto a CFH in fixed puff mode and the CFH weighed, then a second with the CFJH being weighed and so on. The average TPM per rod could be calculated and this was compared with the calculated value expected using the equation above. Tolerable agreement can be obtained – figure 2.

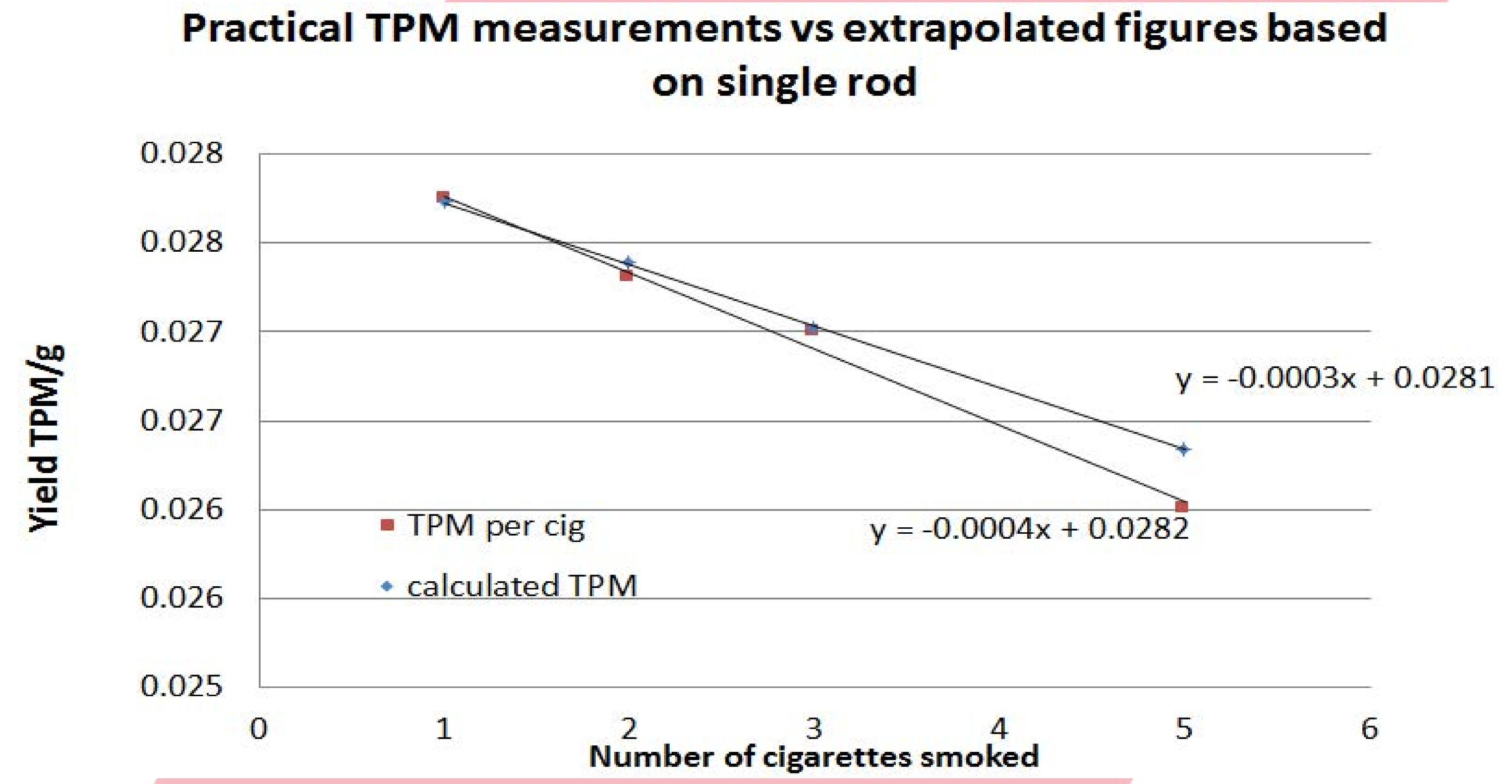

Figure 2: Actual yield for 55mL puffs and 30 second interval and calculated yield based on a single rod calibration using the derived equation (2)

Discussion and Conclusions

As the puff number for the pad increases then desorption increases which may be of significance when considering semi volatile compounds such as phenols [2]. Such desorption will be magnified if high puff counts on a single pad are considered especially when high levels of humectants and water are present e.g. rotary smoking machine and THP products.

This is an effect that can cause some systematic error when contrasting different numbers of puff blocks for ENDS devices, the delivery per puff could be underestimated if a large number of puffs are used in a puff block as there may be significant desorption of humectants and water due to the continual action of puffing (i.e. >50 puffs per block).

This model compound and the "loaded pad" technique predicts the loss that might be expected from a Cambridge filter pad that is repeatedly puffed as might be the case in some experimental designs.

In itself it has limited use but can form the basis of an understanding where systematic errors can creep into experimental design. This is particularly evident when different machine types are used (rotary with inherently large numbers of puffs on a single pad and linear machines with fewer puffs) or when looking at different puff blocks when testing ENDS and THP's.

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