Filtrona Technology Centre

The Role of Filter Technology in Reduced Yield Cigarettes

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In recent years there has been a growing interest in a wide range of chemicals in cigarette smoke, in particular the chemicals considered toxic or carcinogenic. Some authors have speculated that reducing the amounts of such compounds in smoke may give rise to cigarettes that could be considered to be lower risk products. While no clear definition of a lower risk product exists such products would be expected to give lower (or zero) yields of harmful compounds. This has led to an increasing focus on the role of the filter in overall cigarette performance with particular reference to its ability to selectively remove toxic compounds from smoke. Cigarette smoke can be divided into four main phases all of which contain compounds that can be considered harmful or toxic. These are gasses, vapours, semi-volatiles and non-volatiles. At the moment three main methods exist for the reduction of cigarette yields, filtration using fibrous media, adsorption using granular additives and ventilation. Each method of reduction has a different effect on the different phases of smoke, Slide 2. The table shown here summarises the effect of the different reduction methods on the different phases of smoke. As can be seen standard filters tend to reduce semi and non-volatile compounds, the use of carbon can enhance the reduction of vapour and semi-volatile compounds while ventilation tends to reduce all compounds to some extent. To produce a cigarette that is acceptable to the consumer but a potentially lower risk product the ideal solution would be to be able to selectively reduce the harmful compounds in smoke while allowing those responsible for smoker satisfaction to pass through the filter. The complexity of cigarette smoke makes it extremely difficult to identify all harmful compounds but those identified on the Hoffmann list would make a good starting point for removal.

In order to be selectively removed, compounds must be available in smoke in a state that allows selective removal. The only way to selectively remove individual compounds is if they can diffuse to the removal medium and then undergo some adsorption or reaction to be removed from the smoke-stream. As diffusion is critical to selective filtration, volatile and gaseous compounds are available for selective removal but non-volatile compounds are not. Considering the nature of smoke, slide 3, the plot shown here gives the distribution of the compounds between the gas/vapour phase and particulate phase of smoke for the compounds on the Hoffmann list. As might be expected the data generally shows the lower the boiling point, the greater the portion in the vapour phase and the greater the availability for selective removal. The line in blue shows the expected distribution and as can be seen the majority of compounds follow the expected distribution. Notable exceptions are reactive or highly soluble compounds such as Ammonia, Formaldehyde or Hydrogen Cyanide, shown in red, where the availability for selective removal is lower than would be expected from a simple consideration of their boiling point alone. Generally this plot shows many of the compounds of interest are wholly or partly available for selective removal. Important exceptions are non-volatile compounds such as Aromatic Amines, Tobacco Specific Nitrosamines and Benzo [a] Pyrene that are not available for selective removal.

Having established which compounds can be removed, how can filter technology be used in the reduction of these compounds to develop cigarettes with reduced yields that may give rise to reduced risk products, Slide 4. Filter technology can offer a variety of cost effective solutions to the cigarette designer. These include filters with higher tar and nicotine retentions per unit pressure drop than standard acetate filters, more effective carbon filters, the carrying of alternate adsorption or chemisorption materials and constructions which allow the use of ventilation for gas/vapour compound reduction.

Filter options do exist to give higher tar and Nicotine reductions than a standard filter at the same pressure drop. A filter that is being used on many brands in China perhaps because of its compatibility with the tobacco blends used is the CPF filter. This filter is shown in slide 5 and consists of a cellulose acetate filter wrapped with a partially fluted special paper. The flutes can be orientated so they are at the tobacco end of the filter or to the mouth end of the filter, as shown in slide 6. The main advantage of this filter is the cross flow filtration achieved by the special fluted paper which increases the retention of the filter when compared to a cellulose acetate filter at the same pressure drop. This increase in retention can be up to 10% and a plot of a comparison of the retention of a CPF filter with that of a cellulose acetate filter is given in slide 7. An example of how such a filter can be used in a tar reduction program while maintaining a relatively constant cigarette draw resistance is shown in slide 8. For example, if the requirement were to reduce the tar yield of a 15 mg cigarette to around 12 mg without a significant increase in cigarette draw resistance, the best procedure would be to achieve the reduction in 3 or 4 steps. The table in slide 8 shows two of the steps with the CPF filter finally achieving the 12 mg tar yield target at approximately the same cigarette draw resistance. It should be noted that to achieve the 12 mg target with a standard cellulose acetate filter would require an increase in cigarette draw resistance to a level that consumers would find unacceptable.

Orientating the flutes to the mouth end of the cigarette, thus giving a unique appearance has also been used with this type of filter to provide brand differentiation and a counterfeit deterrent. A photograph of the end appearance of the cigarettes is given in slide 9. A further option to enhance the unique end appearance would be to use coloured inner wraps, this greatly enhances the appearance, and hence anti-counterfeiting benefits of this product, Slide 10. The CPF filter has also recently been constructed with a flavour delivery system to allow the extra retention to be used in conjunction with flavour release. An example of this type of filter is shown in slide 11. Another development of this filter has been its use as a segment in a dual filter product. This allows a combination with, for example, a traditional Active Acetate Dual filter to give the product a distinct appearance for brand differentiation while simultaneously utilising the properties of carbon and increased retention efficiency of the CPF filter. An example of such a filter is shown in slide 12 which would be more appropriate for a possible reduced risk product as the carbon would give significant reductions in toxic compounds.

The use of carbon in reduced yield products is now well established as carbon can significantly reduce 23 compounds on the Hoffmann list, the main drawback is that current commercial carbon filters are relatively complex to manufacture. For example to produce the most commonly used

commercial carbon filter the active acetate dual filter requires three manufacturing processes. These are production of the acetate mouth end base rod, production of the base rod containing carbon and combining the two rods into the finished dual filter. Advances in production technology over the last decade have allowed the speed at which the dual rods are produced to increase from about 180 m/min to a maximum of 500 m/min. Despite the advances in these production technologies a carbon product that can be produced in a single manufacturing process is of great interest to the industry in general. Such a product is now available, slide 13.
This is the Active Patch Filter (APF) and consists of a patch of carbon printed on the inner surface of a standard plugwrap on a monoacetate filter. The filter is a single segment filter wrapped in a plugwrap to which granular activated carbon has been applied. The product is also available with a split patch, slide 14, to allow ventilation through the gap in the carbon. At the moment this can only be achieved by on line laser but a version with a porous wrap will be available next year. Other granular adsorbents can be added to the plugwrap such as silica gel or sepiolite or a selective filtration medium. Slide 15 gives the main parameters of filter construction. The preferred additive would be an activated carbon on a standard plugwrap. The carbon loading is 2.9 mg per mm and carbon loading is controlled by patch length. Normally a carbon free 5 mm length is left at the mouth end of the filter and a 3 mm carbon free length is left at the tobacco rod end of the filter. Therefore, for a 25 mm length filter a carbon loading of up to 50 mg can be achieved with an unventilated cigarette, Slide 16. The main benefit of this filter is the higher reductions in vapour phase and semi-volatile components when compared to an equivalent monoacetate filter. The APF is also a clean run filter so that no carbon-bearing portions of the filter are cut through during cigarette manufacturing. A unique property of this filter is that it does not give the same taste usually associated with carbon filters. It has been reported that the taste of this product is similar to monoacetate filters. This makes the filter ideal to introduce activated carbon filters into a traditionally monoacetate market without the necessary adaptation to carbon taste and without introducing processing complexity into an existing cigarette factory. The taste benefits of this filter make it ideal for the introduction of carbon into markets using mainly Virginia flue cured tobacco where taste could be adversely affected through the use of other carbon filter constructions. Slide 17 shows a comparison in performance between an active patch filter, an active acetate dual filter and a monoacetate filter. The main

differences between the carbon products and the monoacetate filter are seen as an increase in the retention of Hydrogen Cyanide, Volatile Aldehydes, Volatile Ketones, Volatile Hydrocarbons and Semi-Volatile Bases. The retention's of Tobacco Specific Nitrosamines, Aromatic Amines and Benzo[a]Pyrene are similar for all three types of filter. Obviously reduction in the yields of the harmful vapour compounds can only help in the development of reduced risk products. Further work is ongoing on other types of mono carbon filter which may be seen in the near future.

Traditionally the carbons used in the cigarette industry have been based on coconut shell carbons which as we have seen give significant reduction of a wide range of compounds considered as harmful. However, they are not selective to any particular individual compound or group of compounds. True selectivity could be considered as the total removal of one particular compound from smoke. Of course removing only one compound may be considered to give a lower contribution to overall risk reduction than the removal of a wide number of toxic compounds. An idea solution may well be considered to be the combination of the use of carbon with an additive to target a particular compound to combine the overall removal of a range of compounds with the selective removal of a targeted compound. Although work is still ongoing to extend the range of these enhanced carbons the first filter product of this type was launched last year, slide 18. This material allows for the targeted reduction of Hydrogen Cyanide and could be used in any type of carbon filter, slide 19. The Hydrogen Cyanide yield of an unventilated cigarette is often between 150 to 400 µg per cigarette depending on the tobacco blend used. Acetate filters give very little filtration of Hydrogen Cyanide. Standard carbon increases the retention of Hydrogen Cyanide but it is still relatively low, especially for aged cigarettes. Hydrogen Cyanide is an extremely toxic irritating gas that causes cilla toxicity in the respiratory tract. In some countries the yield of Hydrogen Cyanide is declared either on pack or to regulatory bodies. Selective removal has long been a target of the cigarette industry, slide 20. This is achieved by using a special impregnated carbon. The selective carbon also increases the overall vapour phase removal given by carbon filters. Naturally this also includes a higher removal of semi-volatile compounds. The removal of Hydrogen Cyanide can be increased to over 90% if sufficient carbon is used. This performance is proven to be stable over time, slide 21. A comparison of the performance of the high activity impregnated carbon with standard coconut shell carbon for some vapour compounds shows the greater reductions that can be achieved. Especially noteworthy is the much higher Hydrogen Cyanide removal of the order of 80 % for 60 mg of carbon compared to 35 % for the same weight of standard carbon. The mechanism of this removal is a chemical reaction rather than physical adsorption so the removal efficiency of Hydrogen Cyanide does not change with time (i.e. when cigarettes are aged). The efficiency of physical adsorption of carbon in a filter does fall with time, slide 22. This plot shows the effect of cigarette storage time on the efficiency of Hydrogen Cyanide removal for the selective carbon and standard carbon. As can be seen the retention of the selective carbon is relatively unchanged with time whereas the standard carbon shows a fall in its removal efficiency. As a result removal of the Hydrogen Cyanide by the selective carbon is around four times that of standard carbon in the aged product. Looking at a wider range of compounds and adding acetate to the comparison the plot in slide 23 shows the retention of various groups of compounds for 6 month old cigarettes. For this test the carbon filters used 60 mg of carbon and the tar retention of all three filters was around 55 %. The most obvious difference is the much higher removal of Hydrogen Cyanide when compared to the standard carbon or acetate filters. For volatile aldehydes, ketones and hydrocarbons the HCNR carbon also removes higher amounts. For semi-volatile compounds like Pyridine and Styrene higher removals for carbon and HCNR carbon are also seen. As the boiling point of compounds increase the carbons have less vapour to remove and so the retention is nearer to that of acetate for the phenols and cresols. For non-volatile compounds such as tobacco specific nitrosamines and Benzo [a] Pyrene the retention of all the filters are very similar to the tar retention. When used with moderate ventilation and filters with about 100 mg of this selective carbon it may be possible to produce cigarettes that are essentially free of compounds like Hydrogen Cyanide, Pyridine and Styrene which can only help the designer of potentially lower risk products.

A major component of cigarette smoke is Carbon Monoxide. In cigarette smoke Carbon Monoxide is formed by the thermal decomposition and incomplete combustion of many of the components of tobacco. Carbon Monoxide is an odourless, colourless gas which is extremely toxic. The toxic effects of carbon monoxide are relatively well known, the most important being its ability to combine with haemoglobin in blood to form carboxyhaemoglobin, more readily than Oxygen, hence disrupting the normal oxygen supply to blood tissues.

This toxic effect, coupled with the relatively high levels in cigarette smoke make the reduction of carbon monoxide of prime concern for the development of lower risk products. At this point in time the only practical way of reducing carbon monoxide in smoke is by the use of filter ventilation. In general ventilation will, as shown in slide 24, reduce the cigarette draw resistance and the yields of all smoke components including tar and nicotine. Filtration by the majority of filters will reduce mainly tar and nicotine. To achieve a highly ventilated cigarette with an acceptable draw resistance a filter with a high-pressure drop is required. But if, for example, a cigarette with a high level of ventilation is combined with high-pressure drop/high retention filter the result will be a very low tar yield and low taste cigarette. If it were possible to use only ventilation to reduce (for example with an empty tube with 50% ventilation) cigarette yields, a cigarette with 50 % ventilation but no filtration would have a theoretical reduction profile as shown in slide 25. The main feature for this plot is the large Carbon Monoxide reduction. If this data is combined with that for different filter types it is possible to compare the removal achieved by 50% ventilation with that for 50 % tar retention and for 50% tar retention combined with carbon. This is shown in slide 26. As previously stated the plot clearly demonstrates that ventilation is the only current practical method of reducing Carbon Monoxide. Ventilation also reduces other gas/vapour phase compounds much more effectively than cellulose acetate filters. Of course if lower levels of ventilation and higher carbon loading were considered carbon would be seen to be the most effective for removing volatile organic compounds. To utilise the effect of ventilation to reduce carbon monoxide but to produce a cigarette with an acceptable draw resistance and tar yield a filter with a high-pressure drop but low tar and Nicotine retention is required. Slide 27 shows how filter tar/Nicotine retention can be reduced. The methods of reducing retention for a filter of a particular pressure drop include reducing filter length, increasing filament denier, and reducing filter circumference or the use of novel materials with high-pressure drop and low retention. A new novel filter construction that meets the high-pressure drop low retention criteria is now available, slide 28, the COR filter. This filter, slide 29, is designed as a triple filter construction with an acetate segment at both ends of the filter. The tobacco rod end segment is low pressure drop low retention but the mouth end segment is high pressure drop low retention. The filter, slide 30, will allow the reduction of Carbon Monoxide yield relative to tar whilst offering acceptable draw resistance, even when combined with high ventilation levels. The COR filter also reduces the deliveries of organic volatiles and other gas phase compounds such as Nitric Oxide.

To illustrate the effect of the filter on the overall cigarette yields and especially the ratio of tar to carbon monoxide let us consider designing a possible 10 mg tar yield cigarette, as shown in slide 31, from a 63 mm tobacco column yielding 25 mg tar and 13.5 mg Carbon Monoxide with a cigarette draw resistance around 115 mm Water Gauge (WG). The overall length of the cigarette is 84 mm and thus a 21 mm length filter is required. One possible solution would be to use a filter with a pressure drop (PD) around 80 mm WG and tar retention about 50 %. This would require a filter ventilation of about 20 % to give the tar target and as shown in slide 32 the Carbon Monoxide yield would be just over 10 mg. An alternative solution would be to minimise retention and maximise ventilation. A filter with a PD of around 30 mm WG with tar retention of 30 % could be used with 43 % filter ventilation. This would give a 10 mg tar yield with a much lower carbon monoxide yield of around 7 mg but at a much too low cigarette draw resistance, just over 50 mm WG. Such a product would be unacceptable to smokers. However, if a high PD low retention filter was used with a PD of 90 mm and tar retention of 30 % the same tar and carbon monoxide yields could be achieved with a much more acceptable cigarette draw resistance. The higher cigarette draw resistance is partially caused by the balance of PD within the filter being different to a standard product. As shown earlier of course ventilation reduces other volatile compounds in smoke. A comparison of a standard 10 mg tar yielding product and a 10 mg tar product made with a carbon monoxide (COR) reducing filter is shown in slide 33. From the data it can be seen that the high PD low retention filter gives lower amounts of all the volatile compounds in smoke – Carbon Monoxide, Hydrogen Cyanide, Volatile Aldehydes, Volatile Hydrocarbons, Volatile Ketones and many others. Of course the use of carbon would allow reduction of many of the compounds reduced by ventilation to a similar or greater extent except Carbon Monoxide. Combining this technique with carbon or selective carbon in the cavity could give products with very low yields of some of the harmful compounds.

As we have seen a considerable number of options already exist for the reduction of toxic compounds in cigarette smoke. However, much work is also being carried out to further increase the reduction of toxic compounds. A cigarette brand is already in the market place using an ion exchange resin in combination with carbon to give reductions of toxic compounds in smoke. This may be the first of many products using a more complex filter construction and multiple removal reagents to reduce the levels of toxic materials in smoke.

Filter technology can make two major contributions to cigarette yield reduction, slide 34. The first is to continue to develop machinery to enable more complex filters to be produced at faster speeds and in a more economical manner. The second is through the development of more options for additives for specific reduction of toxic materials. For example, more active carbons, a greater range of carbons with impregnants to remove specific toxic compounds or groups of compounds, additives that remove toxic compounds through chemical reaction such as ion exchange resins, catalysts, chemicals added to filters to react with specific toxins, surface active fibres and development of other granular materials such as Zeolytes.

The filter of the future will probably be a multifunctional device, manufactured at very high speed containing carbon and a number of selective filtration media. Such devices will give the cigarette designer a great deal of help in producing products that may be considered as reduced risk.

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