



Filtrona Technology Centre

The Role of Filter Technology in Reduced Risk Cigarettes

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When considering the role of filter technology in reduced risk cigarettes the most fundamental question to be answered is what constitutes a reduced risk cigarette. No clear definition of what would be an acceptable reduced risk cigarette currently exists and as would be expected for such a complex subject a number of different views have been expressed.

It is the extreme complexity of cigarette smoke which makes it difficult to give an accurate risk evaluation for exposure to smoke. Classical toxicology considerations for exposure to individual compounds would give a dose response curve as shown in this plot, **fig 2**. The general principal shows that increasing the dose increases the potential risk. That is exposure below or near the threshold level is potentially a lot less harmful than exposure at levels where significant response is experienced. Therefore, although no clear definition of a reduced risk product exists there would appear to be some consensus in the view that reducing exposure to all toxic materials may give rise to products that could be considered reduced risk. However, many years of testing would be needed to confirm the validity of any reduced risk claim. If reduced dose does equate to reduced risk, it is in the field of reducing the dose of various smoke compounds that filter technology can make a contribution to potentially reduced risk cigarettes. Of course it is not possible to measure the yield of every smoke compound so the majority of work looking at reducing yields for potential less harmful cigarettes focuses on the measurement of the compounds referred to as the Hoffmann list.

Two routes would allow a contribution from the filter to help in reducing the dose of various smoke compounds. The first is the development of filter solutions using new materials and the second is the more effective, lower cost manufacture of filters containing granular additives.

If we consider new materials, the vast majority of cigarettes globally use cellulose acetate or a combination of cellulose acetate and carbon as the filter material. Approximately 10% of the current world cigarette market uses carbon filter products and it could be argued that as the carbon filters reduce the yields of many gas/vapour phase toxicants that these are the first step towards commercial reduced risk products. Development of a new more effective granular additive may therefore be a further potential step towards a reduced risk product. An extremely wide range of materials could be used as granular additives, **fig 3**, including alumina's, carbons, catalysts, molecular sieves, **fig 4**, ion exchange resins, sepiolite, silica gels and zeolites. Considering that these materials are available in a wide range of particle sizes, surface area's, and pore sizes and for some, different chemical forms, it can be seen that a huge number of possibilities are available. Also carbon can be produced from any carbonaceous raw material such as coal, lignite, wood, peat, coconut shell, petroleum coke, bones and fruit nuts. In addition it can be seen that by using many of the above materials as supports for chemical reagents the variations become almost infinite.

As carbon is still the most commonly used granular additive in cigarettes any new materials under consideration tend to be compared with the carbon currently used in cigarettes, coconut shell carbon with a surface area of approximately 1100 m²/g. To compare a range of materials for activity towards cigarette smoke, a reproducible method was to introduce a fixed weight of the material into a cigarette during smoking. This is tested in comparison with a control cigarette made by using the same cigarette with an empty cavity. Thus the only difference between the two cigarettes was the bed of material produced by the granular additive as shown here, **fig 5**. To evaluate the effectiveness of the additives the cigarettes are smoked under standard conditions and the yields of a range of compounds measured. The percentage retention of a compound of interest has been calculated as, **fig 6**, the yield of the control cigarette minus the yield of the test cigarette divided by the yield of the control cigarette multiplied by one hundred.

Using this screening technique we have evaluated many granular additives including those currently and previously used in cigarette filters. Time will not allow a review of all materials tested but a comparison of the effectiveness of different carbons with some other granular materials will be discussed. These are, **fig 7**, a standard coconut shell based carbon; a coal based carbon; HCNR carbon, which is a high surface area coconut shell carbon impregnated with a material to reduce Hydrogen Cyanide; a typical silica gel (60 Angstrom pore size) and a weak base anion exchange resin. Some of these materials are currently used in cigarette filters or have been used in the past. They cover a wide range of surface areas, **Fig 8**, from the lowest at 480 m²/g to the highest at 1,600 m²/g. The materials also have a wide range of surface chemistries from the relatively inert carbon, to a more polar surface such as silica gel, to a chemically modified carbon, to the ion exchange resin which will give some purely chemical effects. It should of course be noted that the screening technique only supplies information on the performance of the fresh material it does not give any indication on how the material will perform in an aged product. Active granular additives in general only affect compounds in smoke that pass through the filter in the gas or vapour form. However, it is well known that none of these additives will reduce Carbon Monoxide or Nitric Oxide in smoke, **fig 9**. Therefore, for this work we have looked at some of the Hoffmann compounds with boiling points in the range from about -20 to 240 C. These compounds include many of the well known toxicants such as volatile cyanides, various carbonyls, volatile hydrocarbons and semi-volatile bases. The current cellulose acetate filters are well known to show selectivity towards phenolic compounds and the granular additives so far studied do not increase the reduction in phenolic compounds when compared to cellulose acetate.

If we recall the dose response curve shown earlier a zero dose equals a zero response so in the plots of retention that follow 100% retention is equivalent to a zero yield and therefore a zero response. Looking at the retention of the cyanide compounds first, **fig 10**, it can be seen that the carbons give the largest removal and increasing the surface area of the carbon increases the removal of these two compounds. The coal based carbon gives lower retentions of Hydrogen Cyanide when compared to the other carbons. The ion exchange resin gives good retention of Hydrogen Cyanide but, in general the resin and silica gel give

lower removals than the carbons. Impregnating the carbon with compounds to enhance the removal of Hydrogen Cyanide does increase the retention of this chemical but as for the resins it is a very selective effect as only the retention of Hydrogen Cyanide is increased. However, it is difficult to judge when the Hydrogen Cyanide is in a complex mixture such as cigarette smoke if retention of over 90% is sufficient to reduce the dose to below the threshold level but the general principle is the lower the dose or yield the better.

Turning now to carbonyls, **fig 11**, again it can be seen that carbon is generally the best adsorbent as it gives higher retentions of the compounds and in general retention increases with increasing surface area. Carbons produced from other raw materials such as coal also give relatively high retention of carbonyls. For the carbonyls, the silica gel gives higher retentions than those previously seen in the last plot for cyanides. This is probably due to the more polar nature of the silica gel giving a better adsorption of the polar carbonyls. The ion exchange resin also gives some retention of the carbonyls. Considering now the more volatile of the hydrocarbons, 1, 3 Butadiene and Isoprene, **fig 12**, it can again be seen that carbon gives by far the greatest removal and, increasing surface area increases the retention of the materials. Again the carbons from other raw materials give relatively good retentions. Ion exchange resin and silica gel give very low retentions of these two chemicals. Some less volatile hydrocarbons, Benzene and Styrene, are shown in the next plot, **fig 13**. Again, all the carbons give high retentions with the high surface area coconut carbon giving retentions over 80%. The retention given by the silica gel is low for Benzene but higher for Styrene. The polar nature of the silica gel does not aid the retention of hydrocarbons and silica gel is usually considered a poor material for removing hydrocarbons from smoke. The ion exchange resin gives some reduction of the less volatile hydrocarbons but has little effect on the more volatile chemicals. For all of these volatile compounds in smoke cellulose acetate has low levels of retention.

Semi-volatile bases, **fig14**, such as Pyridine can be retained by most of the materials studied. The polar nature of the Pyridine means that the lower surface area silica gel can retain almost as much Pyridine standard coconut and coal carbons and the silica gel retains over 80% of the Pyridine. The high surface area HCNR carbon retains about 95% of the Pyridine. General reductions of Quinoline are much lower, probably because the boiling point is much

higher and hence the amount of vapour available is much lower. The polar nature of Quinoline allows the silica gel to retain slightly more than the carbons.

The work discussed here has only looked at a snapshot of a few granular materials; many others are currently being studied. For example, as mentioned earlier, carbon can be produced from any carbonaceous raw material and much work is still ongoing in the evaluation of different carbons and including those with added impregnants. In terms of the potential for reduced risk, carbon is currently the best option and some prominent scientists have hypothesised that a major factor influencing the differential lung cancer rate between Japanese and Western smokers is the greater popularity of charcoal filtered cigarettes in Japan. This appears to be a situation where the main stream smoke chemistry, biological assays and epidemiological studies are in agreement, that is, reducing main stream smoke vapour phase toxicants is beneficial (1). Therefore, development of more effective granular adsorbents that can be used alone or in conjunction with standard or new, more effective carbons may give a positive contribution to the potential of risk reduction.

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Once the new materials have been identified they would have to be incorporated into filters. The most common current method for incorporating granular additives in filters is the active acetate dual filter often referred to as the Dalmatian filter, **Fig 15**. This is usually a two segment filter with an acetate mouth end segment and a segment with carbon on tow at the tobacco rod end of the filter. To make such a filter requires 3 processes, the production of the white base rod, the production of the base rod containing carbon and combination of the two rods into a dual filter. In recent years filter production technology has made great advances in the speeds (and hence costs) at which such filters can be produced. For both the base rod containing carbon and the dual rod, machine speeds have more than doubled and the current machines, **fig 16**, for producing dual rods are clean, self-contained high speed manufacturing units. Furthermore, higher weights of carbon can be incorporated using the triple granular filter, **fig 17**. Filtrona's unique Cavitec™ process allows up to two different materials to be placed in the cavity and ensures that the cavities are full. Again, the speed at which these types of filters can be produced has greatly increased over recent years.

To combine more than two granular additives in a filter more complex multi-segment filters may be required and such products, an example of which is shown here, **fig 18**, have been proposed in the past (2). Such a filter

could contain up to three different fibrous filter materials and four different granular additives and development samples of this type have been produced. Also, commercial equipment is now available to produce filters with up to 5 solid segments. So, while there are many ways of incorporating carbon or other granular materials in filters, it is well understood that increased complexity in the filter will generally lead to added cost in the final product. Thus some extremely complex filters may give rise to potentially reduced risk products but their cost would probably mean they tend towards very low volume niche brands that would not make a major contribution to reduced risk for the majority of smokers.

The most recent advances in the use of granular materials in filters have attempted to address the complexity issue by the production of mono-carbon filters. That is a carbon filter made in one machine pass. The first of these filters is the Active Patch Filter™ or APF™. The APF™ filter, **fig 19**, is available as a short single patch or, **fig 20**, as a longer patch for maximum carbon loading. A split patch, **fig 21**, to allow for filter ventilation in the gap between the two carbon patches is also available. The Active Patch Filter™, **fig 22**, was designed to create an effective mono carbon product with the clean running, secondary production advantages of a mono-acetate filter. The filter consists of a patch of activated carbon printed onto the inner surface of the plugwrap. The patch position is flexible. Carbon loading can be up to 3 mg per mm of patch length and total loading is controlled by the length of the patch. The filter gives a similar removal of vapour phase and semi-volatile components as other carbon filters with the same carbon weight but has been assessed to have less carbon taste. For manufacturers that wish to take advantage of the filtration properties of carbon it is considered that this filter would a good first step to introduce carbon into markets that are traditionally monoacetate or for use with blends such as Virginia which are sometimes considered to be less compatible with carbon

Irrespective of how carbon is added to a filter its overall effect is to reduce the yield of a range of mainstream smoke toxicants that are not very effectively filtered by a standard cellulose acetate filter. Indeed Laugesen and Fowles have speculated that due to the known reductions of many smoke toxicants given by carbon, regulation to require effective charcoal filters is now long overdue (3). Should such requirements become fact, effective mono-carbon filters could be the answer.

In conclusion, **fig 23**, it can be seen that the road to a potentially reduced risk cigarette could follow many routes. Until the exact nature of a reduced risk product is defined, the final goal will always be difficult. At the moment carbon is still the most effective granular filter additive available. It is expected that the global trend in the tobacco industry will be a continuing reduction of the yields of all compounds in smoke. The filter used will continue to play a major part in this effort and will continue to get longer and probably lower in circumference. It could be that this will involve the more complex filters with one; two or more granular additives used on premium brands as potential reduced risk products.

Perhaps mono-filter solutions, which allow reductions in a range of toxicants that, may be more readily available and acceptable to a wider range of smokers, might be the way to go. If the use of carbon, **fig 24**, does reduce risk, would changing every brand to a carbon filter bring about a reduction in risk for all smokers? Much research effort is being concentrated on the development of more efficient filters and additives which can be used in them. Future filters may well become more complex, multi-segment devices but an effective monofilter will always have a role to play. As always in the cigarette industry the next few years will bring some very interesting developments.

References

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