85% of Tobacco Smoke is Invisible – a confirmation of previous claims.

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Contributors: the original concept for the article came from Andrea Crossfield, when researching the provenance of the claim that 85% of tobacco smoke is invisible. Ivan Gee led both the data analysis and the drafting of the paper with significant contributions from Sean Semple and Adrian Watson. All contributors reviewed and edited the final manuscript. Ivan Gee is the guarantor for the article.

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Tobacco control campaigns frequently make use of statistical and scientific information to inform the public and policy makers about the dangers of tobacco smoke. It is clearly crucial for the credibility of tobacco control programmes that accurate, scientifically valid information is used in these campaign materials and Siegel [1] highlights the importance of ensuring that the evidence base of these materials is scientifically sound.

In 2002 the British Medical Association produced a report on passive smoking that indicated that:

"Almost 85 per cent of second-hand smoke is in the form of invisible, odourless gases" [2].

This referenced a US National Research Council report [3] as the source of this information but this report does not directly explain the 85% figure. At no point does the US report suggest that 85% of second-hand smoke or environmental tobacco smoke (ETS) is invisible.

However, despite the lack of unambiguous scientific evidence, the suggestion that 85% of tobacco smoke is invisible has been widely reported as fact in authoritative reports as well as numerous campaign materials, both in the UK and internationally. These include the influential Royal College of Physicians' document on 10 reasons to make public places smokefree[4], successful TV campaigns[5] and the Tobacco Control Resource Centre[6].

We have examined the available data on tobacco smoke compositions and believe that a justification of the 85% figure can be made and we present details of this in this letter.

In order to determine how much of tobacco smoke is 'invisible' it is necessary to obtain estimates of typical particle phase concentrations (the visible components) and gaseous concentrations (the invisible fraction). This gas to particle ratio can then be used as an estimate of the ratio between

invisible and visible components. Many studies of tobacco smoke composition have been conducted but not all of these report both particulate and gaseous materials. Nelson et. al.[7], working for RJ Reynolds tobacco company have conducted numerous detailed chemical studies of environmental tobacco smoke using environmental chambers. They report a range of gaseous and particle concentrations in ETS for cigarettes from 11 countries.

Of the gaseous components contained in tobacco smoke, nitrogen (N_2) oxygen (O_2) and carbon dioxide (CO_2) predominate but carbon monoxide (CO) is by far the largest contributing pollutant that has potential health impacts. Total volatile organic compounds represent the second largest potentially harmful gaseous component, but because they are a mixture of unspecified individual compounds and reported in micrograms/L, they cannot be converted to the same units as ETS particle measurements. As such, we chose to use CO alone to estimate the gas to particle ratio; using CO only results in more conservative estimates.

Particles are reported by Nelson et al as RSP (respirable suspended particles) using an impactor with a 3.5 µm cut off point. For tobacco smoke particle size distributions RSP is a good estimate of the total suspended particulate (TSP) content [8]. RSP concentrations ranged from 1285 µg/m^3 to 1740 µg/m^3, with the average RSP across cigarettes from all 11 countries being 1545 µg/m^3. Average CO concentrations ranged from 5.6 µL/L to 7.3 µL/L and across all 11 countries averaged at 6.6 µL/L.

CO concentrations in µL/L were converted to µg/m^3 based on a molecular weight of 28 and 1 mole of an ideal gas occupying 24.45 L at standard ambient temperature and pressure (SATP) [9] allowing for the proportion of CO by mass in ETS to be calculated. Table 1 shows the RSP and CO concentrations with the calculated contribution from CO to the mass of ETS aerosol for the lowest, highest and average ETS concentrations as presented by the Nelson data.

Table 1: Carbon Monoxide (CO) and Respirable Suspented Particle (RSP) concentrations in environmental tobacco smoke (ETS) together with the calculated % contribution of CO to ETS aerosol mass.

	CO (µL/L)[7]	CO (µg/m^3)	RSP (µg/m^3) [7]	% contribution of CO to ETS
Lowest concentrations	5.6	6412	1285	83.3
Highest concentrations	7.3	8359	1740	82.8
Average ETS concentrations	6.6	7578	1545	83.1

These estimates suggest that approximately 83% of tobacco smoke is in a gaseous form that is not visible, supporting the previously reported estimates of 85%. We also note that recent evidence would suggest that most ETS particulate matter is of less than 100nm diameter [10] and, as such, likely to be 'invisible' to the naked eye, further increasing the proportion of ETS by mass that would not be visible to smokers and non-smokers alike. We therefore consider it reasonable for tobacco control campaigns to continue to report that 83% of the harmful components within ETS are invisible.

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