Combustion-generated carbonaceous urban atmospheric UFPs: Efficiencies of face mask control of urban atmospheric particulate pollution: A pointer to control of future pandemics

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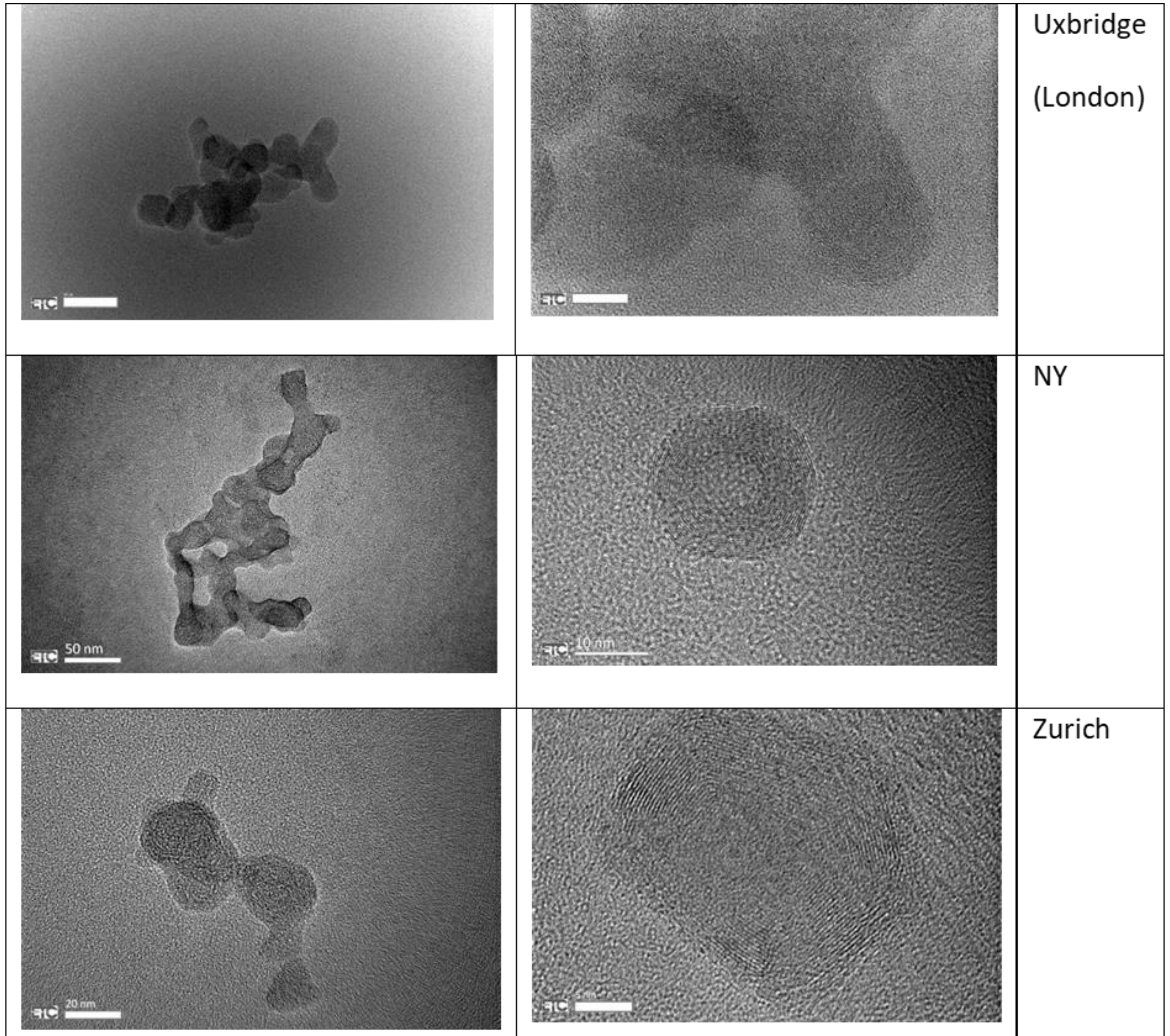
Introduction. Each day an adult human inhales on average 13.6kg [1] or 10,000 litres of air that potentially contain 0.1-10 trillion particles [2]. Some of these may be ultrafine carbonaceous combustion- and traffic-generated particles (UFPs) smaller than 100nm [3]. They are remarkably similar if one lives in Uxbridge, New York or Zurich:



TEM of combustion-derived urban atmospheric UFPs in 3 cities

Others may be microbiological and bioaerosols (e.g. bacteria, fungi, viruses [4], excreta of insects and spores) and larger PM2.5 or PM10 pollutants [3]. TEM says COVID-19 virus is about 60-140nm [5,6]. Since we 'cannot cease breathing for more than a few minutes' [7] the atmosphere that bathes each of us is critical; locally this air is part of our personal ecosphere [8] and within it are a number of potential threats: molecular, particulate and bioaerosol. It has been suggested that pollution of urban air in London contributed to the death of Ella Kissi-Debrah in 2013. It is therefore worthy of assessing how [9] filtration of critical atmospheric pollutants by face masks can be most effective. Masks can protect wearers and neighbours [8]. Air speeds at the mouth vary during inspiration-expiration [10]; typical nasal breathing involves air velocities of 1m/s [11]. The filtration efficiency [12,13] (FE) of non-valved [13] and valved (diodic) [14] surgical masks has been assessed with viruses and UFPs [15,16].

Experimental. The masks used here were:

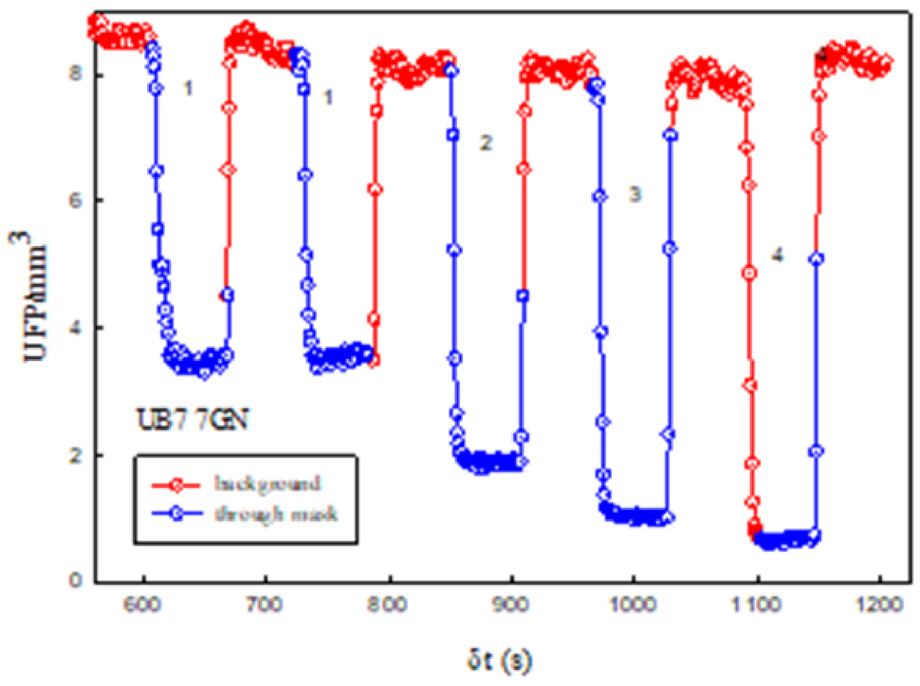
- 2 stainless steel mesh filters (fine (100μmx100μm) and coarse (500μmx500μm))
- a cycle mask (Respro City Anti-pollution filter; medium size)
- an Oarsports bandana-snood (with a mesh openings of 500μm),
- a do-it-yourself (DIY) disposable mask (Supatool; medium size) and
- a valved diodic Honeywell FFP2 KN95 (Chinese) respirator (where the FE=96%-97% but decreased a little on sterilisation [17])

Analysis used a P-Trak 8525 (TSI) condensation particle counter of airborne ultrafine particles (UFPs) (20nm-1μm; 0-5 x 10^5 particles/cm^3) at a sample flow rate of 100cm^3/min and inlet flow rate of 700cm^3/min [18]. In the case of the diodic mask the inlet air velocity (0.56m/s) was decreased to 0.005m/s (to widen the area of filter analysis to incorporate the valve). The ultrafine particles prevailing in the urban air in a covered carpark at UK postcode UB7 7GN were used to test the filtration efficiency of these masks.

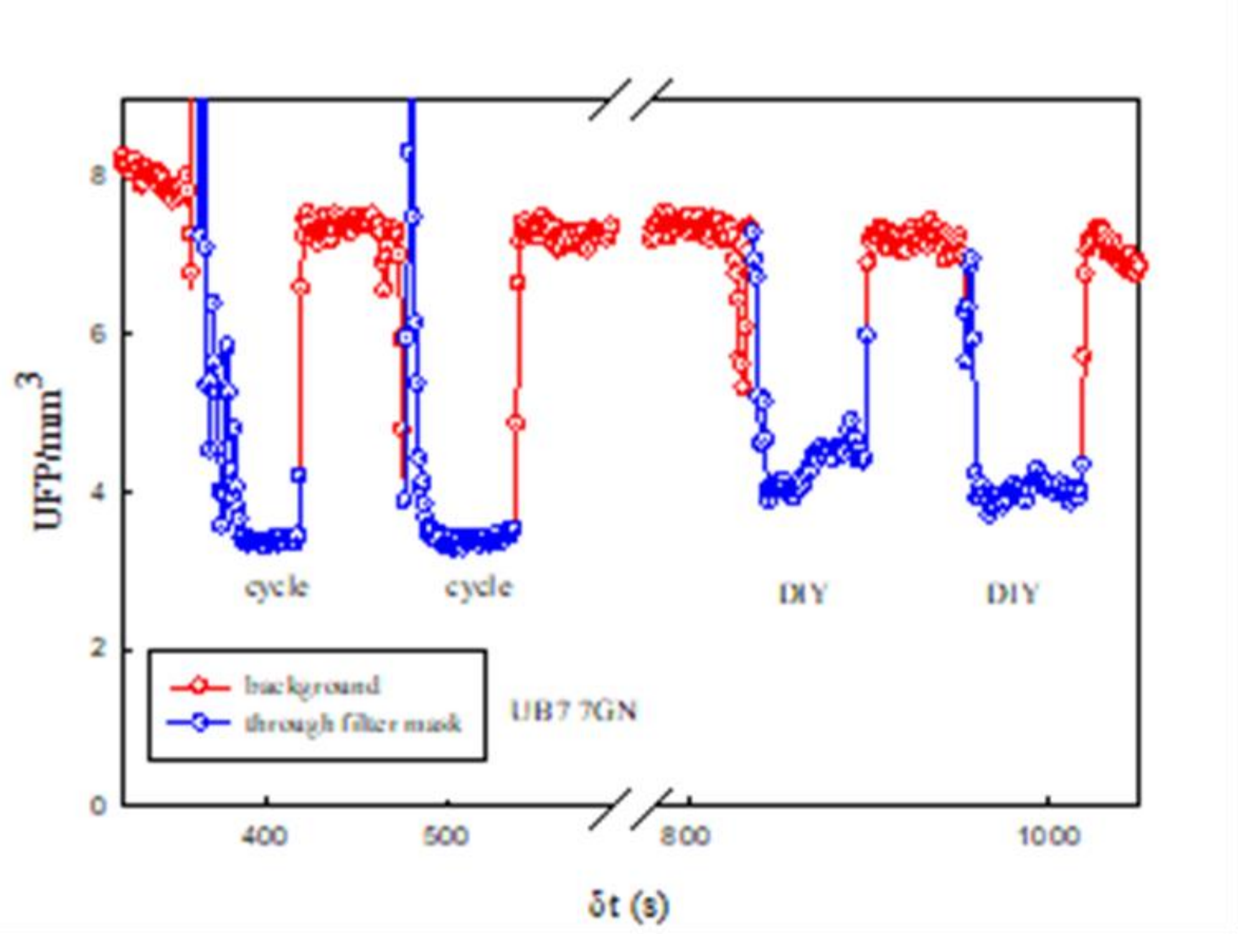
Results. Fine (100μmx100μm openings) and coarse (500μmx500μm openings) stainless steel filters had UFP filtration efficiencies of 50.87% and 7.29%.

As one would expect, the bandana UFP filtration efficiency increased progressively from 45% to 90% as the number of layers increased from 1 to 4. This is an important finding for control of current particulate air pollution and future pandemics.

Red=background
Blue=through mask



The UFP filtration efficiency of cycle and DIY masks was no better than a single layer bandana.



The diodic valve KN95 mask was more than twice as efficient at filtering UFPs in an inhalation mode (blue) than in an exhalation mode (green), presumably protecting the wearer more than those around them.

We now need to investigate which type of urban carbonaceous UFPs are filtered out and how this can be made selective with filter surface modification.

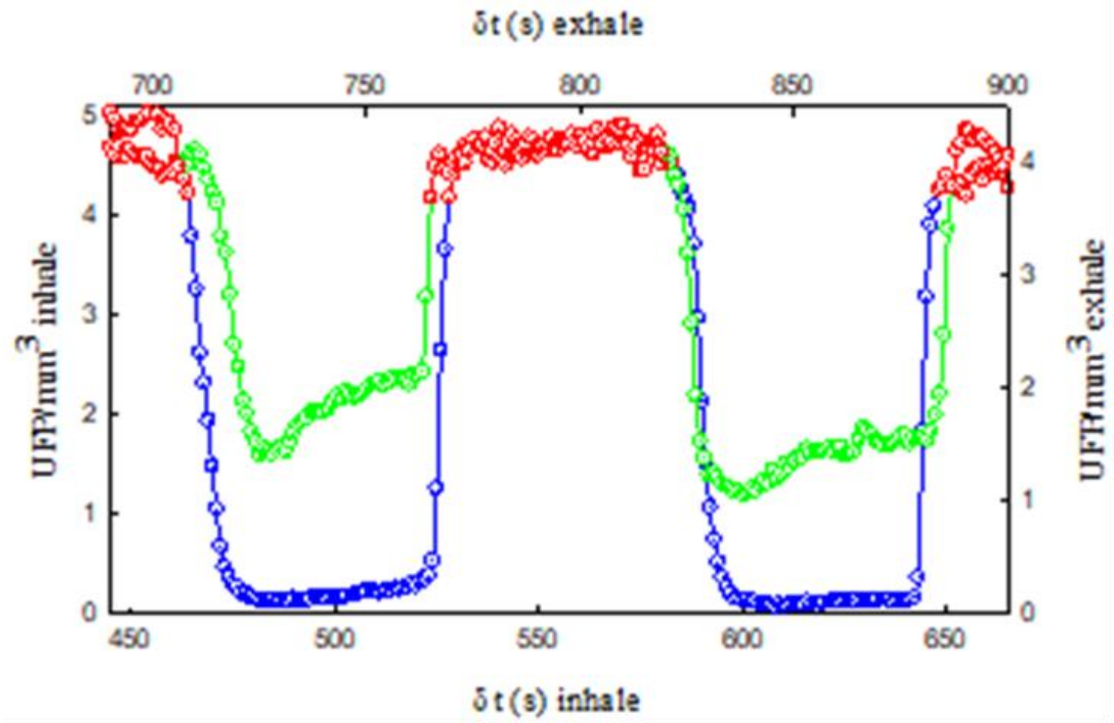


Table 1. UFP filtration efficiencies (%) of various masks

Snood-bandana (1 layer)	44.74
Snood-bandana (2 layer)	68.84
Snood-bandana (3 layer)	74.70
Snood-bandana (4 layer)	89.48
Cycle	42.52
DIY	41.93
Diodic KN95 FFP2 (inhale mode)	92.28
Diodic KN95 FFP2 (exhale mode)	45.42

Control of airborne infection [19] and particulate pollutants [9] is important as we wait for all to be vaccinated against COVID-19, ‘soon shall every one be mask'd’? [20]. Probably. Some masks are more effective than others, leading to personal ecospheres of differing quality.

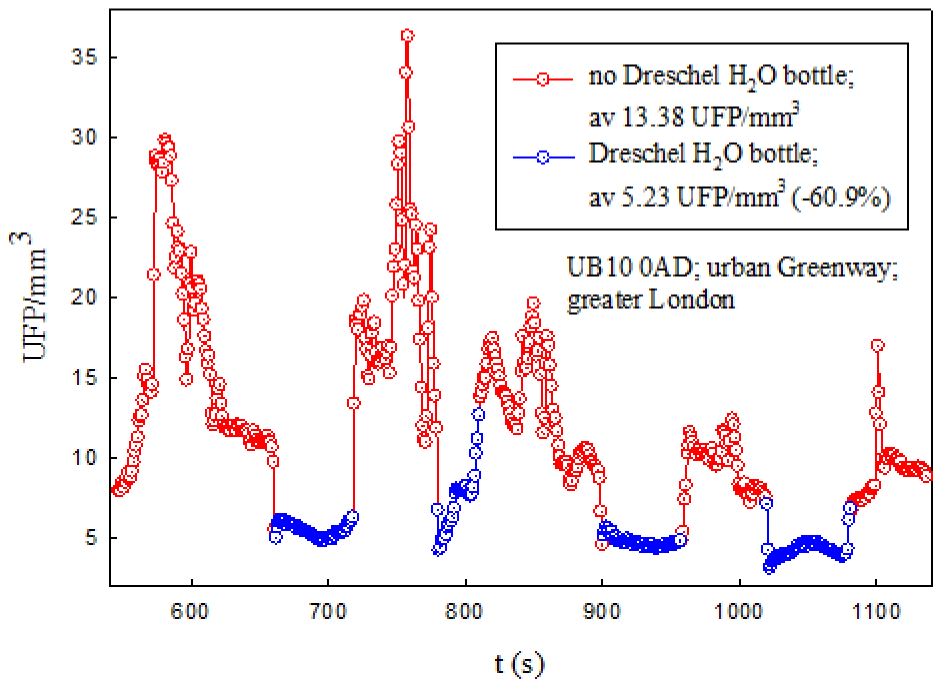
Discussion. At one extreme, a single layer kerchief/bandana/snood/scarf may provide no end of sartorial elegance [21] but is unlikely to provide protection to current particulate air pollution and in the current and future pandemics. Bandana efficiency depends on their multi-layered use, which is not easy to monitor and impedes facial recognition [22].

At another extreme, diodic valved surgical masks appear to protect the wearer more than neighbours. Future bio-based facemasks [23] or comfortable biomimetic facemasks may emerge as we fill gaps in our understanding through coordinated research.

Technology is required that determines the effectiveness of facemasks being used. 70 years ago we knew of the problem deposition of atmospheric particulates in human lungs [24]. Now we can follow this in real time and devise masks that offer full protection. In future we need a green usable face mask technology that will protect us from this pollution as we transition to zero-carbon economies.

We are currently exploring the varying respiration and retention of airborne carbonaceous UFP by those of different gender, age group, fitness level and ethnic background so that they may be better protected in the future.

The authors were also intrigued that passage through water stripped out carbonaceous UFPs from the atmosphere and this may affect the impact of the particles on our health and the modification of masks to protect us from these (and other) airborne hazards.



Varying real-time UFP concentrations in urban air (red) and levels remaining for 1min periods after filtering (blue) in an inhalation mode through distilled water (lowering concentrations by more than 60%).

Conclusions. For the moment face masks show varying efficiencies for protecting us from inhaling combustion-generated airborne ultrafine particles (UFPs) varies. Real-time technology to spot ineffective facemasks of their end-of-useful-life may need deploying. In addition, our understanding of the design of facemask filtering out carbonaceous UFPs will enable us to design even better masks for future pandemics.

Thank you for listening virtually.

References. [1] Anon Investigation of air pollution. Lancet Supplement i (27th Oct 1917); [2] Tsuda A. Compr.Physiol. 3,1437-1471 (2013); [3] Kwon, H.S. Expert.Molec.Med. DI 10.1038/s12276-020-0405-1 (2020); [4] Milton D. K. Plos Pathogens 9,e1003205 (2013); [5] Leung, W. W-F. Sep.Purif.Technol. 245,116887 (2020); [6] Zhu, N. New Engl.J.Med. 737-731 (20th Feb 2020); [7] Giberne, A. The ocean of the air. Seeley, London (1894)'; [8] Garrett L. The coming plague p786; [9] Kumarathasan P. Part.Fibre Toxicol. 15,34 (2018); [10] Tena A. F. Eng.Applic. Comput.Fluid Mechan. 9,187-198 (2015); [11] Zhang, R. PNAS 117,14857-14863 (2020); [12] Konda A. ACS Nano 14,6339-6347 (2020); [13] Canini L. PlosOne 5,AR e13998 (2010); [14] Radonovich L. J. JAMA 322,824-833 (2019); [15] Eninger R. M. Ann.Occup.Hyg. 52,385-396 (2008); [16] Eninger R. M. J.Occup.Environ.Hyg. 5,286-295 (2008); [17] Cai, C. JAMA Network Open 3,e2012099 (2020); [18] Matson, U. Aero.Sci.Technol. 38,487-495 (2004); [19] Tang J. W. J.Roy.Soc.Interface 6,S737-S746 (2009); [20] Shakespeare W. Loves Labours Lost. Act V. Scene II; [21] Bee P. The Times/Times 2 p.4 (15th July 2020); [22] Venkatakrishnan D. 1st Internat.Conf. Advancements in Automation and Control (ICAAC) 573,442 (2014); [23] Das O. Sci.Tot.Environ. 736,139611 (2020); [24] Davies, C.N. Ann.Occup.Hyg. 7,169,(1964)