Submission to Senate Enquiry

1. <u>Introduction: Air pollution - A global contemporary risk</u>

There have been a number of important developments over the past several months that have strengthened what we know about the impact of air pollution on health, provided new evidence and emphasised the significance of ambient particulate matter in general. These include:

- A powerful, multi-dimensional study, published as a series of articles in *The Lancet* in December 2012, demonstrated that "*Worldwide, the contribution of different risk factors to disease burdens has changed substantially, with a shift away from communicable diseases in children towards non-communicable diseases in adults*", with ambient particulate matter pollution ranked among the key contemporary risks (Lim et al., 2012).

- A project, '*Review of evidence on health aspects of air pollution – REVIHAAP',* co-funded by the European Union and in collaboration with the World Health Organisation, has provided answers to 22 questions in relation to the review of European policies on air pollution, as well as addressing the health aspects of these policies (WHO, 2013). Based on an extensive body of new scientific information on the health effects of particulate matter, ozone and nitrogen dioxide, the group concluded that the "*new evidence supports the scientific conclusions of the WHO Air Quality Guidelines, last updated in 2005, and indicates that effects can occur at air pollution concentrations lower than those used to establish the 2005 Guidelines".*

  In relation to ultrafine particles (UFP; <0.1 μm), the report showed that there is "*increasing epidemiological evidence on the association between short-term exposure to UFPs and cardiorespiratory health, as well as the central nervous system. Clinical and toxicological studies have shown that ultrafine particles act, in part, through mechanisms not shared with larger particles that dominate mass-based metrics, such as* $PM_{2.5}$ *or* PM_{10}."

- In a very recently published report, '*Understanding the Health Effects of Ambient Ultrafine Particles',* the Health Effects Institute (HEI) concludes that, while there have been a growing number of laboratory and field studies of the effects of UFP, "*toxicologic studies in animals, controlled human exposure studies and epidemiologic studies have not provided consistent findings on the effects of exposure to ambient levels of UFPs, particularly in human populations. The current evidence does not support a conclusion that exposure to UFPs alone can account in substantial ways for the adverse effects that have been associated with other ambient pollutants, such as* $PM_{2.5}$" (HEI, 2013)

  The panel concluded that: (i) motor vehicles, especially diesel engines, have been important sources of emissions and exposure to UFPs; (ii) there are clear differences between UFPs and larger particles in terms of their lung deposition, lung clearance and potential for translocation to other parts of the body; (iii) there is suggestive, but not consistent, evidence of adverse effects from short-term exposure to ambient UFP based on experimental and epidemiologic studies; (iv) no strong evidence was identified to indicate that the effects of short-term exposure to UFP are dramatically different from those of larger PM, however information on long-term exposure is not available.

2. <u>Particulate Matter - Its Sources and Effects</u>

2.1 Ambient particulate matter: General characteristics

One of several ambient environments of global significance is the urban environment. The majority of the worlds human population (currently 50.4%, but expected to reach 65.3% by 2050 (CIA, 2011)) reside in ever-growing urban agglomerations. These figures are higher in Australia, with urban dwellers already comprising 68.4% of the Australian population (ABS, 2008), hence the significance of ambient urban particulate matter.

There are many different ways to characterise ambient particulate matter, and its routine monitoring is conducted in terms of mass concentration of particles smaller than 2.5 or 10µm in aerodynamic diameter, as $PM_{2.5}$ and PM_{10} fractions, receptively. $PM_{2.5}$ is otherwise termed fine particles, while $PM_{2.5-10}$ are termed coarse particles. UFPs are measured in terms of number, rather than mass concentration (or more accurately, particle number concentration in the submicrometer range). Legislators often take the view that since UFPs are smaller than $PM_{2.5}$ or PM_{10}, they are already captured by measurements of these mass metrics. It is true that their mass is, but since the mass of these particles is only a small fraction of the total mass of particles smaller than 2.5 µm, in reality, $PM_{2.5}$ measurements usually give little information about UFP.

Another important point is that different sources contribute to $PM_{2.5}$ or PM_{10} and UFPs, and therefore, the chemical composition or toxicity of these size fractions is very different.

2.2 Sources

Airborne particles originate from a range of different sources, and the spatial and temporal contribution of these sources varies, as does human exposure. Larger particles, the coarse fraction ($PM_{2.5-10}$), originate mainly from mechanical processes such as grinding, the breaking of material or surface dust re-suspension. Different types of sources contribute to the $PM_{2.5}$ fraction, most importantly combustion (vehicle emissions, biomass, coal and industrial burning, and coal dust re-suspension), as well as mechanical processes. However, since combustion generated particles mainly comprise of UFPs, only the largest combustion particles and the smallest mechanically generated particles add to $PM_{2.5}$ mass. In addition to combustion generated particles, those particles formed through secondary processes, called secondary organic aerosols (SOA), are also a major contributor to UFPs.

As such, these different particles, together with gaseous pollutants, constitute a complex pollution mixture. Elemental carbon, primary organics and SOAs are normally components of the mixture, particularly in urban environments, and are products of primary particle emissions and secondary formation processes. Of particular importance is that SOAs are a product of complex physical and chemical interactions and the end product is different to the vapours which formed them. SOAs are becoming an important component of urban air pollution, not only in terms of number concentration, but also mass. Over the past decades the mass concentration of larger particles ($PM_{2.5}$ or PM_{10}) has decreased, and without the surface area of these larger particles on which organic vapours could condense, they now more frequently nucleate to form SOA. In the mid-1990's, when the team at ILAQH, QUT began the routine monitoring of UFP in Brisbane, we rarely saw SOA peaks in the particle size distribution, however now it is almost a daily occurrence (Cheung et al., 2011).

2.3 Spatial and temporal distributions

Numerous studies around the world have demonstrated reasonably homogenous spatial distributions of both $PM_{2.5}$ and PM_{10} in urban airsheads, with differences in concentration between near road and urban background usually not larger than 30%. In contrast, the spatial distribution of UFP is heterogeneous, with differences between urban background and hot spots, such as in tunnels or near busy roads, reaching up to two orders of magnitude (Morawska et al., 2008).

The past decade has seen a significant increase in the monitoring of UFP concentration, with several reviews recently being published on this topic, land use regression (LUR) models being developed to show spatial variation in urban UFP concentration, and several large studies on this topic currently being conducted in Europe and several countries around the world. As such, there is already a good understanding of the relationship between background UFP concentrations versus urban and extreme concentrations, and also that hot spots can make a potentially significant contribution to the overall exposure of urban populations.

It is important to note that this heterogeneity is not captured by monitoring conducted at central stations, away from traffic, and therefore, different monitoring designs are necessary for data collection in relation to exposure and health assessments. Most of the studies available to date are based on population-average exposures, characterised by 24-hour and annual average concentrations measured at central monitoring sites. Therefore, additional efforts to capture the temporal-spatial variation of particle matter, and integrating personal exposures in epidemiological studies, seem to be mandated. These studies are considered necessary to further assess the potential independence of long-term and short-term health effects, particularly in relation to very short-term exposure to extreme concentrations, such as near busy roads, transport corridors, tunnels or in underground mines.

2.3 Health effects

No threshold. Regardless of particle metrics, all of the existing epidemiologic evidence clearly shows that there is no lower limit of exposure where there is no impact.

Ultrafine particles are considered of particular significance because of their potential to travel deeper into the lungs, as well as into the bloodstream and brain. The main gaps in understanding the impacts of UFPs on heath include: (i) a lack of epidemiologic evidence in relation to the effect of UFPs on health, with only a handful of studies published on this topic; (ii) an insufficient understanding of whether the effects of UFP are independent to those of $PM_{2.5}$ and PM_{10}; and (iii) unanswered questions in relation to which physical or chemical characteristics of UFPs are of most significance to health. The most commonly measured characteristic is particle number concentration, followed by size distribution, however surface area is also hypothesised to be of key importance. More and more studies point to the significance of surface area rather than particle number (specifically in relation to smaller particles) as an indicator of health risk, since this is the best measure of particle interaction with the lung tissue.

Coarse particles. The studies available to date have provided evidence for the association between short-term exposure to coarse particles ($PM_{2.5-10}$) and health. However, this evidence is insufficient for proposing a switch from regulating PM_{10} to regulating coarse particles. In particular, studies assessing the long-term health effects of coarse particles, as well as those indicating the relative importance of the various sources of particles, including desert dust, volcano ash, re-suspended road or coal dust, among others, are lacking.

Emerging health outcomes. Literature on the long-term health effects of $PM_{2.5}$ points towards additional systemic health effects beyond the respiratory and cardiovascular system. Exposure response functions would need to be established for these additional outcomes, assessing different stages of vulnerability within the life-span of humans. More studies are needed that will specifically look at the neuro-cognitive function, metabolic outcomes and other potentially impacted organ systems, so that these potential effects could be included in future health impact assessments.

Exposure to the total pollutant mix. There have been a number of studies showing health impacts from exposure to the total pollutant mix. The main question is whether there are differences in the health effects of particles from different sources, when the concentrations and other physical characteristics of the particles are comparable.

The role of the primary and secondary organic aerosol particles. There is strong evidence that organic compounds and transition metals are most responsible for the toxicity of airborne particles, despite compromising only a very small fraction of particle mass. However, the mechanisms by which they cause adverse health effects are yet to be fully understood. Some recent toxicologic studies indicate that particulate matter-related reactive oxygen species (ROS) (both particle bound and produced in cells upon exposure) and the resulting oxidative stress they cause, may play a role in initiating a number of adverse health effects. Taking into account that the organic fraction (primary or secondary) is ubiquitous in particulate matter found in the urban atmosphere, more studies are needed to understand how critical this fraction is, in terms the toxicity of these particles.

3. The Populations Most at Risk

Studies have shown that the populations most at risk are by virtue of: (a) Age - the very young and very old are more susceptible than middle age people, (b) Compromised health - asthmatics and people with respiratory and cardiac problems are more vulnerable; and (c) Location - people living or working near hot spots where concentrations are significantly elevated or specific conditions make the particles more toxic.

4. The Standards, Monitoring and Regulation of Air Quality at all Levels of Government

From the above, the following policy implications emerge:

a) There is a critical need for the routine monitoring of UFPs, to provide input for epidemiologic studies and in turn, the development of regulations (it is unlikely that regulations would be developed without exposure-response relationships);
b) Contrary to $PM_{2.5}$ and PM_{10}, the spatial distribution of UFPs is highly heterogeneous, which implies that different monitoring designs are needed (we cannot fully capture the effects based on monitoring at a central location alone);
c) Source apportionment is needed to distinguish between different source contributions, as well as primary versus secondary UFPs (different policy approaches may be needed to control primary and secondary UFPs); and
d) Despite the gaps in knowledge, we know enough to distinguish between 'normal' and highly elevated UFP concentrations. Therefore, local measures can and should be considered to help lower exposure to high UFP concentrations (there is no lower safe threshold for health effects from $PM_{2.5}$ and PM_{10}, thus, there may not be one for UFPs either).

5. Any Other Related Matter

The International Laboratory for Air Quality and Health (ILAQH), established in 1993, is part of the Institute for Health and Biomedical Innovation (IHBI) and the Institute for Future Environments (IFE) at the Queensland University of Technology (QUT). ILAQH undertakes research, postgraduate training and consultancy in the complex, interdisciplinary field of air quality and its impact on human health, with a specific focus on ultrafine and nanoparticles. To address the challenges related to the interdisciplinary nature of air pollution and its impact on human health, academics from a number of Faculties within QUT are involved with the programs undertaken by the ILAQH, including discipline areas such as: physics, chemistry, microbiology, mathematics, public health and engineering. The expertise of the ILAQH team is strengthened by close collaboration with a number of government and non-government organisations. Through joint research, lecturing and postgraduate student supervision, the ILAQH also collaborates closely with a number of North American, European and Asian research and tertiary organisations.

ILAQH has built up a scientific program which is internationally recognised through a high publication rate in reputable international journals, visits to the facility by scholars from around the world, and invitations for ILAQH's key researchers to address international conferences and participate in international initiatives. In Australia, both the State (Queensland) and Federal government, as well as non-government organisations regularly seek the expertise of this facility.

ILAQH is a Collaborating Centre of the World Health Organisation on Research and Training in the field of Air Quality and Health, since 2004.

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