Airborne Particles in Industrial Environments -Characteristics and Health Effects

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In industrial production, airborne particles have been a threat to workers' health for several hundred years. In 1713 the Italian physician Bernadini Ramazzini published *De Morbis Artificum (*Ramazzini, 1713*)* with descriptions of health hazards in a number of different occupations. He made observations of workers who were exposed to mineral dust: "Stone-cutters, sculptors, quarrymen, and other such workers are usually troubled with a cough, and some of them contract asthmatic affections and become consumptive. … when the bodies of such workers are dissected, they have been found to be stuffed with small stones". This was probably the first published report about the disease we today call "silicosis". There were no means to monitor or measure the air to ensure safety at that time. Many thousands of destroyed lungs and early deaths can be attributed to silicosis throughout the centuries.

More than 200 years after Ramazzini's observations it was agreed at a pneumoconiosis conference in Johannesburg (Orenstein, 1959) that a standard size fraction (approx. less than 5 μm) should be collected and gravimetrically determined in order to get a measure reflecting the degree of risk of exposure to quartz dust. Simple instruments based on pre-collection of the coarse fraction and collection of fine particles on filters for subsequent mass determination were developed which were used to test the air. Increased awareness, monitoring routines and new production techniques have led to a very low incidence rate of silicosis today in developed countries. Various instruments based on mass determination have been developed in order to monitor the air in workplaces. Almost all of them are based on mass determination of "total dust" or "respirable fractions". Asbestos fibre determinations are an exception where the measurements have been based on number concentration of fibres within certain dimensions.

New technologies generate smaller particles

There are three ways that particles can be released to air in workplaces:

1) *Disintegration and resuspension* of materials in mechanical processes such as grinding, machining, drilling and wear. The mass of airborne particles is dominated by coarse particles, but there is always a tail in the particle size distribution downwards to the fine and nanometre size regions. This is especially the case if the mechanical treatment occurs in conjunction with heat release.
2) *Nucleation-condensation processe*s where gases/vapours nucleate/condense to small particles which sometimes agglomerate to aggregates or attach to coarser particles. Processes such as welding, thermal spraying, soldering and thermal cutting create nanoparticles.
3) *Chemical reaction*. If reactions between gases produce solid or liquid phase reaction products, nanoparticles can be created. Such reactions occur in combustion.

Exploitation of nanotechnology can drastically increase emissions of ultrafine nano-sized particles into the air in production, manufacturing, treatment, handling, usage, waste disposal and recycling and as the result of accidents such as fires.

Small airborne particles can cause a variety of serious deceases
Airborne particles can cause traditional pneumoconiosis diseases such as silicosis and asbestosis, different forms of cancer in the airways, allergies and asthma. Furthermore, extensive epidemiological studies have shown that increased concentrations of airborne particles are associated with respiratory and cardiovascular mortality and morbidity even at the comparatively low concentrations in larger European cities (Brook et al. 2004; Pope et al. 2002). The World Health Organisation has estimated that 100 000 deaths (725 000 years of lost healthy life) in Europe can be attributed to exposure to airborne particles (WHO 2002; Ezzati et al. 2002) each year.

Concentrations of both coarse, fine and nanometre-sized particles are often orders of magnitude higher in industrial workplaces than in public environments. A 10 µm particle carries 10^9 more mass than a 10 nm particle of the same density, i.e. a few coarse particles can totally dominate the measured aerosol mass in an industrial workplace even when there are high concentrations of nanoparticles. In standard industrial hygiene mass measurements, the nano-sized particles are normally not included in the determinations.

Aerosol Based Nanotechnology (ABN) facilitates pro-activity for health safety and environment in nanotechnology development
Traditional simple exposure metrics based on mass determinations such as PM_{10} $PM_{2.5}$, "Thoracic" and "Respirable fractions" are not sufficient to fully describe effects on health and environment. Particle populations in real environments are complex mixtures of particles from different sources with strongly varying chemical composition and sizes. As more knowledge of the underlying toxicological mechanisms has become available and more sophisticated particle characterisation techniques have been developed, there is a potential for more relevant measures based on aerosol technology.

Characterisation for health effect assessment should include: 1) determination of relevant deposition site (skin, eyes, nose, trachea, bronchi and alveoli) and 2) relevant measures such as particle concentration (expressed as mass, surface area and number), particle size distribution, particle shape and morphology, chemical and biological constituents, particle solubility and hygroscopicity.

Aerosol Technology offers a variety of methods and instruments for characterisation (Willeke & Baron, 2001). A few examples of studies are given here: Liao et al. (1999) studied the airborne particles with advanced aerosol instrumentation and measured heart rate variability They found a relation between particles and cardiovascular effects in a home for the elderly. Spanne et al.(1999) showed that a standard industrial hygiene method based on impinger collection had very low collection efficiency for particles less than about 1000 nm. Spanne & Bohgard (2001) developed a method to quantify reactive ultrafine particles using an aerosol particle condensation technique; Löndahl et al. (2005) constructed and used an aerosol technology based instrument for in-situ determination of lung deposition of 20-800 nm particles; Dahl et al. (2005) quantified emissions of nanometre-sized particles from wear between tyres and road.

There is a need for dedicated aerosol based methods for exposure studies and methods to assess risk in the early stages of technical development. The knowledge of fundamental mechanisms from aerosol technology thus derived should be incorporated into the entire development and production process. Otherwise, we may have to wait centuries as we did from Ramazzini's report on illness in 1713 to the Johannesburg Conference in 1959 for relevant measures.

Pro-active measures will save lives and health.

References

Brook R.D., Franklin B., Cascio W., Hong Y.L., Howard G., Lipsett M., Luepker R., Mittleman M., Samet J., Smith S.C. & Tager I. (2004) Air pollution and cardiovascular disease - A statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association. *Circulation* 109, 2655-2671

Dahl A, Gharibi A., Swietlicki E**.,.** Gudmundsson A, Bohgard M, Gustafsson M.& Blomqvist G. (2005), Traffic-generated emissions of ultrafine particles from the road surface – tire interface, *Submitted to Atmospheric Environment*

Ezzati M., Lopez A.D., Rodgers A., Vander Hoorn S. & Murray C.J.L. (2002) Selected major risk factors and global and regional burden of disease. *Lancet* 360, 1347-1360

Liao, D., Creason, J., Shy, C., Williams, R., Watts, R., & Zweidinger, R. (1999) "Daily variation of particulate air pollution and poor cardiac autonomic control in the elderly", *Environmental Health Perspectives, 107, 521 - 525.*

Löndahl J, Pagels J, Swietlicki E., Zhou J., Ketzel M., Massling M. & Bohgard M. (2005) A Set-up for Field Studies of Respiratory Fine and Ultrafine Particle Deposition in Humans, submitted to Aerosol Science and Technology

Orenstein, A.J., ed., *Proceedings of the 1959 Pneumoconiosis Conference*, Johannesburg, Churchill, London, 1960.

Pope C.A., Burnett R.T., Thun M.J., Calle E.E., Krewski D., Ito K. & Thurston G.D. (2002) Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Jama-Journal of the American Medical Association* 287, 1132-1141

Ramazzini B. (1713) *De Morbis Artificum* (2nd edition) Translated by W. C. Wright (1940) *Diseases of Workers*, University of Chicago Press, Chicago

Schneider T., Sundell J., Bischof W., Bohgard M., Cherrie J.W.,Clausen P.A,. Dreborg S,. Kildesø J, Kjærgaard, S.K., Løvik M, Pasanen , P. (2003) "EUROPART". Airborne Particles In the Indoor Environment. A European Interdisciplinary Review of Scientific Evidence on Associations between Exposure to Particles in Buildings and Health Effects , *Indoor Air 13 (1):38-48*

Spanne M, Grzybowski M. & Bohgard M (1999) Collection Efficiency for Sub-Micron Particles of a Commonly Used Impinger, *Am. Ind. Hyg. Assoc. J.,60, 540-544*

Spanne M & Bohgard M, (2001) A New method for Sampling of Reactive Compounds in Airborne Submicrometre Particles Using a Condensing Agent, *J Aerosol Science 32 S1, S1013-1014*

WHO (2002) World Health Report 2002. Geneva, World Health Organization

Willeke K, Baron P (ed.) (2001): *Aerosol Measurement: Principles, Techniques and Applications,* 2nd Edition, John Wiley & Sons