Experimental Determination of Particle Deposition onto the Human Eye

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EXPERIMENTAL DETERMINATIOIN OF PARTICLE DEPOSITION ONTO THE HUMAN EYE.

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ABSTRACT

We perform studies of deposition of airborne particles onto the human eye. A mannequin with transparent and sticky foils covering its eyes is exposed to particles of fused alumina in a windtunnel. The airborne particle size distribution is simultaneously measured with an Aerodynamic Particle Sizer, APS. The particles on the foils are counted and measured with an optical microscope connected to an image analyzer.

Calibration between the APS determinations of particle size and number and the optical microscope determinations has been performed for particles of fused alumina.

KEYWORDS

deposition, human eye, windtunnel, aerodynamic particle sizer, optical microscope, particles of fused alumina,

INTRODUCTION

Deposition of particles onto human eyes is a problem in many areas for instance in connection with allergies and exposure to airborne man-made mineral fibers. The importance of deposition of particles onto the eyes is also disscused in connection with eye trouble when working in front of cathode ray tube displays.

The objective of the study is to investigate the mechanism of deposition of airborne particles onto the eyes. The experiments are done with a mannequin in a wind tunnel. The deposition rate dependence on parameters as air velocity, degree of turbulence, orientation to the air flow is determined.

The work is a cooperative project between the National Institute of Occupational Health, Denmark and the Lund Institute of Technology, Sweden.

METHODS

The deposition of airborne particles onto human eyes is studied in a wind tunnel. The cross sectional area of the wind tunnel is $1 \cdot 1\ m^2$. A mannequin with transparent and sticky foils covering its eyes is exposed to an aerosol. The powder used is fused alumina (grade designation F500, Washington Mills Electro Minerals Limited, Manchester, UK), and it is generated by a dispersion generator (RBG 1000, Palas GmbH, Karlsruhe, Germany). The airborne particle size distribution is simultaneously measured with an Aerodynamic Particle Sizer (APS model 3310, TSI, Inc., St.Paul, MN, USA), (Remiarz et al., 1983). The APS determine the aerodynamic particle diameter of the particles over the range 0.5 - 30 μm. The particles on the foils are counted and measured with an optical microscope (model Vanox-T, Olympos) connected to an image analyzer (model VIDAS, Kontron). The smallest particles are brougt into focus and the projected area of each particle is determined with the optical microscope and the projected area diameter is calculated. Parameters that influence the deposition rate are studied. The air flow in the wind tunnel is operated at three air velocities 0.5, 1 and 3 m/s. The mannequin is orientated at 0, 90 and 180 degrees with respect to the forward-facing direction. At a air velocity of 1 m/s and the mannequin facing the wind, the influence of the degree of turbulence is investigated. The air velocity and degree of turbulence is measured with an anemometer system (IFA 100, TSI Inc). The results from the experiments are presented as deposition velocity as a function of the aerodynamic particle diameter and with the orientation of the mannequin, the air velocity and degree of turbulence as parameters.

To facilitate the use of optical microscopy measurements of the deposited particles and simultaneous measurements of the airborne particles with the APS, number and size calibration have to be performed. The calibration between the size determinations of the particles of fused alumina measured by the APS and the optical microscope is performed by determining the cutoff diameters for four impactors with both the instruments (Gudmundsson et al., 1991). The number calibration procedure is performed by sampling simultaneously with a membrane filter (filter type HAWP 02500, Millipore Corp., Massachusetts, USA) and with the APS. The particles are collected isokinetically and with thin-walled probes.

In the APS the particles accelerate through an orifice and pass two laser beams. The light scattered is detected and amplified with a single photomultiplier. Each particle creates a pair of pulses. Two signal processors working independely of each other, the small-particle processor (SPP) and the large-particle processor (LPP), measure the time difference between the pulses. The transit time is related to aerodynamic particle diameter through calibration with spheres of known geometric diameter and particle density. The SPP detect particles between 0.5 μm and 15 μm and the LPP between 5 μm and 30 μm. There are a lot of counting rules for the SPP and the LPP, for instance the LPP and the SPP counts only particles if each pulse in the pulse pair have an amplitude greater than 3 V and 20 mV, respectively. In the APS several different case of coincidence effects occurs (Heitbrink and Baron, 1991). For instance, if only one puls is detected from a particle, a phantom particle can be created when a pulse from an another particle occur while the processor is open. The counting efficiency and the magnitude of coincidence effects of the APS is dependent on the gain of the photomultiplier tube, the thresholds of the two signal processors and the particle concentration. The photomultiplier tube gain and the 20 mV and 3 V thresholds are adjusted so that the counting efficiency is as high as possible for the LPP, without creating phantom particles, and the SPP creating so few phantom particles as possible. To maintain the size of the effects due to counting coincidence, the particle concentration is held at the same level for all experiments. During the experiments the particle concentration is constant, within ±10%.

RESULTS AND DISCUSSION

The size calibration between the aerodynamic particle diameter measured with the APS and the projected area diameter measured with the optical microscope has been performed by Gudmundsson et al. (Gudmundsson et al., 1991). The calibration data is shown in table 1.

Impactor	Optical microscope		APS		
				Without density effect correction	With density effect correction
calculated aero-dynamic cutoff (um)	number of measurements	projected area diameter (um)	number of measurements	aerodynamic particle diameter (um)	aerodynamic particle diameter (um)
1.95	4	2.10 (0.26)	6	1.76 (0.03)	1.64
4.05	3	4.17 (0.08)	5	3.96 (0.08)	3.47
10.08	5	9.02 (0.88)	4	9.59 (0.14)	7.90
20.08	4	15.68 (2.14)	5	17.54 (0.85)	14.05

Table 1. The 50% cutoff diameters of the impactors measured with the optical microscopy and the APS. The standard deviation of the 50% cutoff diameters is also given.

A pilot study of the deposition onto the eyes has been performed. The mannequin was facing the wind at a wind velocity of 1 m/s and the degree of turbulence was about 3%. The result is shown in figure 1. By visual examination it is obvious that most of the particles are deposited on the central area of the eye.

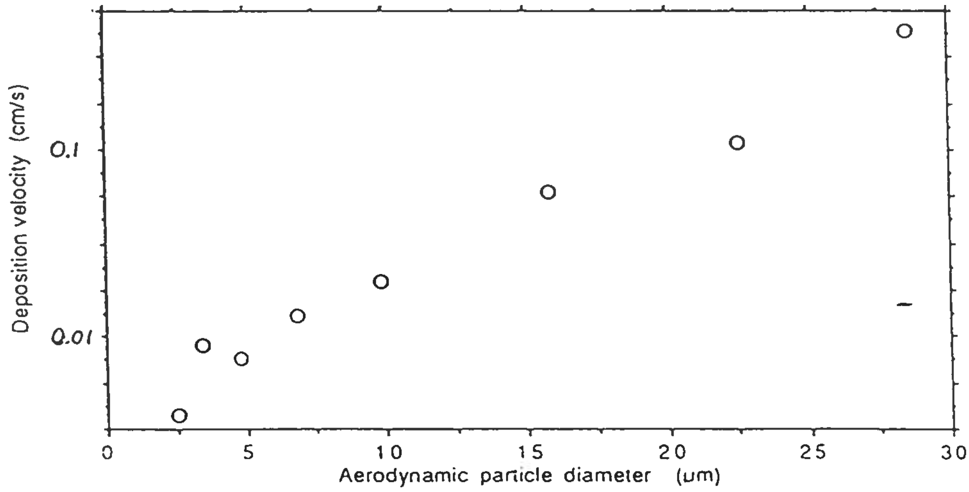

Figure 1. The deposition velocity onto a human eye as a funcion of the aerodynamic particle diameter. The mannequin is facing the wind. The air velocity is 1 m/s and the degree of turbulence is 3%.

To obtain quantitative results with high accurarcy a careful calibration of the counting efficieny of the APS measurements has to be performed. The penetration losses in the sampling tube to the APS and the counting efficiency of the APS will be investigated.

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