Measurement of ultra fine aerosols at workplaces in Switzerland

P. Steinle, P. Thali and A. Gutzwiller, Suva (Swiss National Accident Insurance Fund), Lucerne, Switzerland

Introduction:

There is both rising concern about the risks associated with engineered nanoparticles, as well as an awareness of the possible health effects of ultra fine aerosols (UFA) that originate from various sources, mainly combustion processes. With the availability of new measurement equipment, occupational health institutes are now being asked to assess these workplace exposures.
The Swiss National Accident Insurance Fund has taken up the challenge on multiple levels. A variety of ongoing projects are focused on developing both a better understanding, and a better assessment of the health risks posed by UFA. Provisional recommendations for the handling of nanoparticles have also been established. Measurements at a variety of workplaces have been conducted to obtain an overview of the types of exposure present in different branches of industry.

Materials and Methods:

Measurement strategy and –equipment are according to [1)] and [2)]. As no personal sampling devices are available, stationary measurements are performed in the vicinity of workplaces and/or emission sources. High size-resolution SMPS or high time-resolution electrical diffusion battery measurements allow for the assessment of number concentration and size distribution of the aerosols. Surface concentration can be calculated from these parameters. Stationary measurements are backed up with hand-held CPC-measurements for source investigations. In cooperation with EMPA, aerosols of interest are occasionally collected and subsequently analyzed by TEM/EDX.

Results and Discussion:

Activities of Suva in the field of ultrafine aerosols.
- Exposure reduction by supporting the VERT-project: Cooperation to develop efficient and rugged particulate traps.
- Financial support for the development of measurement equipment: Electrical diffusion battery (fore-runner of DiSC), thermal/ electrostatic precipitator to sample particles for TEM-analysis, standard aerosol generator (CAST).
- Participation in the establishment of a European measurement convention for ultrafine aerosols [1)].
- Exposure assessment of the different branches of industry (Tab. 1).
- Publication of provisional recommendations for workplace protection while handling nanoparticles.
- Supporting the IST-“Nanoinventory” to estimate the prevalence of nanoparticle application in Swiss industry.
- Supporting the transfer of knowledge, e.g. by sponsoring the ETH-conference on combustion generated nanoparticles.

Provisional recommendations for workplace protection.
These recommendations follow the principles for other dangerous substances and are published on http://www.suva.ch/nanopartikel.
- Substitution (dispersions, granulates or compounds instead of powders)
- Confinement (enclosures, local exhaust ventilation, HEPA-filters, swabbing instead of blasting, eventual negative pressure)
- Reduction of the exposure through organizational policies (limited access, shorter exposure times, detailed handling instructions)
- Personal protection (FFP3, gloves, overalls, goggles)
- Specific guidelines are given for the most used bulk-nanomaterials (carbon black and fumed silica)

Table 1: Results of measurements of ultrafine aerosols at different workplaces.
Measurements were conducted as outlined in the text in the years 2004 – 2007. Values are usually averages over the activity-related measurement periods of one to several hours. Where the number of measurements (n) is <3, the range (min. – max.) refers to fluctuations over the measurement period.

Industry / Activity	Number concentration [# /cm³]					Geometric mean of size distribution [nm]				[n]
	min.	max.	mean	median	90% perc.	min.	max.	mean	median	
Nanotechnology	2'200	53'000	15'000	6'800	39'000	15	100	57	64	11
Polymer processing	4'900	174'000	88'000	79'500	160'000	45	98	63	57	6
Powder coating	13'000	41'000	26'000	23'000	37'000	47	65	53	47	3
Chemical production	30'000	250'000	120'000	---	---	29	43	37	---	2
Welding	85'000	2'700'000	610'000	234'000	2'070'000	29	106	73	68	14
Tunnel construction	27'000	830'000	230'000	165'000	407'000	30	122	69	77	10
Traffic (customs, roadside)	30'000	330'000	120'000	59'000	280'000	13	69	29	24	7
Warehouse (forklift traffic)	36'000	90'000	62'000	61'000	86'000	19	75	41	40	5
Gravel plant	23'000	54'000	36'000	---	---	31	39	35	---	1
Indoor shooting range	180'000	1'400'000	420'000	---	---	53	71	64	---	1
Crematory	34'000	41'000	38'000	---	---	---	---	---	---	2
Gastronomy	24'000	110'000	62'000	51'000	98'000	26	70	43	34	3
Office	5'000	53'000	16'000	8'700	34'000	13	84	58	61	6
Outdoor air	2'600	27'000	12'000	8'500	21'000	13	78	53	50	11

The variations in the number and nature of ultra fine aerosols both between and within various branches of industry are huge. Generalizations are hardly possible; there is often no correlation with traditional parameters such as respirable dust or soot. Workplace exposure, but also the effectiveness of means of protection must therefore be assessed individually.
All values in table 1 were measured outside of personal protection devices. Additional measurements showed that such devices are very useful: Number concentration at the welding shop with the highest load came down to ~500 particles/cm^3 when measuring within the powered air purifying respiratory protection system.
Low particle concentrations are usually found in the nanotechnology-industry, with outdoor UFA-concentrations sometimes exceeding the indoor values, if handling is appropriate. Size distribution measurements or even TEM-single particle analysis are necessary for the distinction between engineered and non-engineered UFA.
High number concentrations are associated with hot processes such as weapons firing, polymer processing, welding and combustion engine exhausts, with values ranging from 1 – 5 x 10^4 in the background and du-ring work breaks, to 10^5 – 10^6 particles/cm^3 during work sessions, and up to several million particles/cm^3 inside the exhaust plumes of engines.
Handling of non-nanoscale powders could be shown to create normally no UFA-concentrations above background levels. At tunnel construction sites, both soot particles from diesel engines without particulate traps as well as high amounts of ultra fine rock dust from blasting and grinding can be found.

Literature:

1) Berufsgenossenschaftliches Institut für Arbeitsschutz (BGIA) 2007: Ultrafeine (Aerosol-)Teilchen, deren Agglomerate und Aggregate. BGIA-Arbeitsmappe 0412/5, BGIA, St. Augustin (D)

2) National Institute for Occupational Safety and Health (NIOSH) 2006: Approaches to safe nanotechnology – an information exchange with NIOSH. http://www.cdc.gov/niosh/topics/nanotech/safenano/pdfs/approaches_to_safe_nanotechnology.pdf

Measurement of ultra fine aerosols at workplaces in Switzerland

P. Steinle, P. Thali and A. Gutzwiller, Suva (Swiss National Accident Insurance Fund), Lucerne, Switzerland

There is both rising concern about the risks associated with engineered nanoparticles, as well as an awareness of the possible health effects of ultra fine aerosols (UFA) that originate from various sources, mainly combustion processes. With the availability of new measurement equipment, occupational health institutes are now being asked to assess these workplace exposures.

The Swiss National Accident Insurance Fund has taken up the challenge on multiple levels. A variety of ongoing projects are focused on developing both a better understanding, and a better assessment of the health risks posed by UFA. (Box 1). Provisional recommendations for the handling of nanoparticles have also been established (Box 2). Measurements at a variety of workplaces have been conducted to obtain an overview of the types of exposure present in different branches of industry (Table 1).

Box 1: Activities of Suva in the field of ultrafine aerosols.

Exposure reduction by supporting the VERT-project: Cooperation to develop efficient and rugged particulate traps.

Financial support for the **development of measurement equipment**: Electrical diffusion battery (fore-runner of DiSC), thermal/ electrostatic precipitator to sample particles for TEM-analysis, standard aerosol generator (CAST).

Participation in the establishment of a European **measurement convention** for ultrafine aerosols [1].

Exposure assessment of the different branches of industry (Tab. 1).

Publication of **provisional recommendations for workplace protection** while handling nanoparticles (Box 2).

Supporting the IST-"Nanoinventory" to **estimate the prevalence of nanoparticle application** in Swiss industry.

Supporting the **transfer of knowledge**, e.g. by sponsoring the ETH-conference on combustion generated nanoparticles.

Measurement strategy and –equipment are according to [1] and [2]. As no personal sampling devices are available, stationary measurements are performed in the vicinity of workplaces and/or emission sources. High size-resolution SMPS or high time-resolution electrical diffusion battery measurements allow for the assessment of number concentration and size distribution of the aerosols. Surface concentration can be calculated from these parameters. Stationary measurements are backed up with hand-held CPC-measurements for source investigations.
In cooperation with EMPA, aerosols of interest are occasionally collected and subsequently analyzed by TEM/EDX.

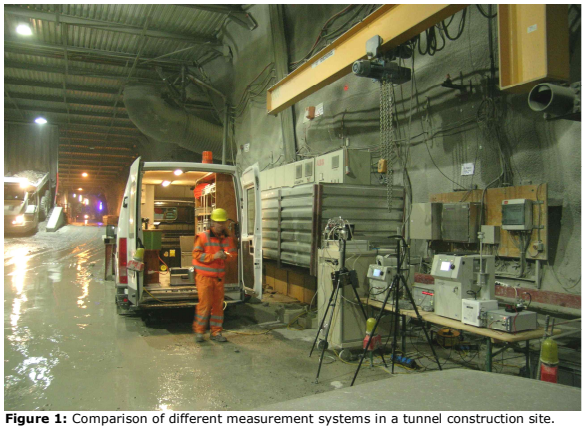

Figure 1: Comparison of different measurement systems in a tunnel construction site.

Table 1: Results of measurements of ultrafine aerosols at different workplaces.
Measurements were conducted as outlined in the text in the years 2004 – 2007. Values are usually averages over the activity-related measurement periods of one to several hours. Where the number of measurements (n) is <3, the range (min. – max.) refers to fluctuations over the measurement period.

Industry / Activity	Number concentration [# /cm³]					Geometric mean of size distribution [nm]				[n]
	min.	max.	mean	median	90% perc.	min.	max.	mean	median	
Nanotechnology	2'200	53'000	15'000	6'800	39'000	15	100	57	64	11
Polymer processing	4'900	174'000	88'000	79'500	160'000	45	98	63	57	6
Powder coating	13'000	41'000	26'000	23'000	37'000	47	65	53	47	3
Chemical production	30'000	250'000	120'000	---	---	29	43	37	---	2
Welding	85'000	2'700'000	610'000	234'000	2'070'000	29	106	73	68	14
Tunnel construction	27'000	830'000	230'000	165'000	407'000	30	122	69	77	10
Traffic (customs, roadside)	30'000	330'000	120'000	59'000	280'000	13	69	29	24	7
Warehouse (forklift traffic)	36'000	90'000	62'000	61'000	86'000	19	75	41	40	5
Gravel plant	23'000	54'000	36'000	---	---	31	39	35	---	1
Indoor shooting range	180'000	1'400'000	420'000	---	---	53	71	64	---	1
Crematory	34'000	41'000	38'000	---	---	---	---	---	---	2
Gastronomy	24'000	110'000	62'000	51'000	98'000	26	70	43	34	3
Office	5'000	53'000	16'000	8'700	34'000	13	84	58	61	6
Outdoor air	2'600	27'000	12'000	8'500	21'000	13	78	53	50	11

The variations in the number and nature of ultra fine aerosols both between and within various branches of industry are huge. Generalizations are hardly possible; there is often no correlation with traditional parameters such as respirable dust or soot. Workplace exposure, but also the effectiveness of means of protection must therefore be assessed individually.

All values in table 1 were measured outside of personal protection devices. Additional measurements showed that such devices are very useful: Number concentration at the welding shop with the highest load came down to ~500 particles/cm³ when measuring within the powered air purifying respiratory protection system.

Low particle concentrations are usually found in the nanotechnology-industry, with outdoor UFA-concentrations sometimes exceeding the indoor values, if handling is appropriate. Size distribution measurements or even TEM-single particle analysis are necessary for the distinction between engineered and non-engineered UFA.

High number concentrations are associated with hot processes such as weapons firing, polymer processing, welding and combustion engine exhausts, with values ranging from 1 – 5 x 10^4 in the background and during work breaks, to 10^5 – 10^6 particles/cm³ during work sessions, and up to several million particles/cm³ inside the exhaust plumes of engines.

Handling of non-nanoscale powders could be shown to create normally no UFA-concentrations above background levels. At tunnel construction sites, both soot particles from diesel engines without particulate traps as well as high amounts of ultra fine rock dust from blasting and grinding can be found.

Figure 2: Hand-held measurement of UFA in a welding-shop to evaluate the effectiveness of personal respiratory protection.

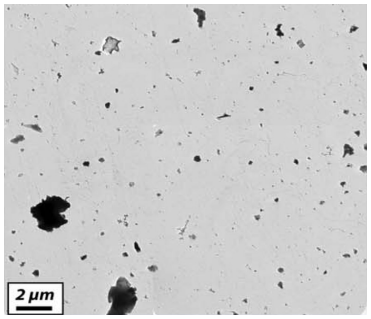

Figure 3: TEM bright field image of blasting dust. Most fragments are in the size range of 140 nm and are of geological origin.

Box 2: Provisional recommendations for workplace protection.

These recommendations follow the principles for other dangerous substances and are published on http://www.suva.ch/nanopartikel.

Substitution (dispersions, granulates or compounds instead of powders)

Confinement (enclosures, local exhaust ventilation, HEPA-filters, swabbing instead of blasting, eventual negative pressure)

Reduction of the exposure through organizational policies (limited access, shorter exposure times, detailed handling instructions)

Personal protection (FFP3, gloves, overalls, goggles)

Specific guidelines are given for the most used bulk-nanomaterials (carbon black and fumed silica)

Literature:

[1] Berufsgenossenschaftliches Institut für Arbeitsschutz (BGIA) 2007: Ultrafeine (Aerosol-)Teilchen, deren Agglomerate und Aggregate. BGIA-Arbeitsmappe 0412/5, BGIA, St. Augustin (D)

[2] National Institute for Occupational Safety and Health (NIOSH) 2006: Approaches to safe nanotechnology – an information exchange with NIOSH. http://www.cdc.gov/niosh/topics/nanotech/safenano/pdfs/approaches_to_safe_nanotechnology.pdf

suvaPro