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Nanoparticle usage and protection measures in the manufacturing industry – a representative survey

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ABSTRACT

Background: Addressing the risks of nanoparticles requires knowledge about release into the environment and occupational exposure. However, such information is currently not systematically collected, therefore this risk assessment lacks quantitative data. **Objective:** The goal was to evaluate the current level of nanoparticle usage in the Swiss industry as well as the health, safety and environmental measures, and the number of potentially exposed workers. **Methods:** A representative, stratified mail survey was conducted among 1,626 clients of the Swiss National Accident Insurance Fund (SUVA). SUVA insures 80,000 manufacturing firms, representing 84% of all Swiss manufacturing companies. **Results:** 947 companies answered the survey (58.3% response rate). The extrapolation to all Swiss manufacturing companies results in 1,309 workers (95% confidence interval: 1,073 to 1,545) potentially exposed to nanoparticles in 586 companies (95%-CI: 145 to 1,027). This corresponds to 0.08% of workers (95%-CI: 0.06% to 0.09%) and to 0.6% of companies (95%-CI: 0.2% to 1.1%). The industrial chemistry branch showed the highest percentage of companies using nanoparticles (21.2%). Other important branches also reported nanoparticles. Personal protection equipment was the predominant protection strategy. Only a minority applied specific environmental protection measures. **Conclusions:** This is the first nationwide representative study on the use of nanoparticle in the manufacturing sector. The information gained can be used for quantitative risk assessment. It can also help policy makers design strategies to support companies developing a safer use of nanomaterial. Noting the current low use of nanoparticles, there is still time to proactively introduce protective methods. If the predicted "nano-revolution" comes true, now is the time to take action.

INTRODUCTION

Nanoparticles have a maximal diameter of 100 nm in at least three dimensions.[1] Nanoparticles and their agglomerates are suspected of having a potentially negative impact on health and environment.[2],[3] Nanoparticles are used for the manufacturing of products that are available on the global market. For risk assessment studies, toxicological effects need to be combined with information about exposure probabilities and exposure levels. However, information on exposure is still basic and needs to be elaborated [4] in other countries as well as Switzerland. Occupational and environmental exposure assessment for the whole working population is currently based on modelling, but models are only as accurate as their data. Currently they need to use diverse, sometimes descriptive sources.[5] So far only a few literature sources present data on nanomaterials in industry that could be used for modelling and quantitative risk assessment.

Several reports showed in the past that there are known nanoparticle applications and potential products [6],[7],[8] and several studies investigated the use of nanoparticles in companies or products. For example UK's DEFRA study was designed as a voluntary reporting system (*http://www.defra.gov.uk/environment/nanotech/index.htm)* and the German BAUA survey investigated the handling of nanoparticles focused on the nanotechnology sector.[9] However, none of them provided systematically acquired data on the prevalence of nanoparticles in the production sector or the consumer goods of their country.

In 2007/8 a targeted survey among 197 Swiss companies evaluated the use of nanoparticles in the Swiss industry.[10] It showed that several types of nanoparticles are already used in 43 of the 197 companies; it showed that the median reported quantity of handled nanoparticles was 100 kg/year and that the protection means mainly focused on personal protection. However, that survey was designed as a pilot study providing descriptive

data only. The preliminary survey provided an overview on the different kinds of nanoparticle applications in industry and the protection means used in companies that were known to handle nanomaterials. It did not however investigate the prevalence of nanoparticle applications in the Swiss industry. To complete the qualitative data of the pilot study described above, this new study was created as a layered representative survey to provide an accurate quantitative estimation of the nanoparticle applications prevalence in certain Swiss industrial branches.

This representative survey investigated the number of companies using nanoparticles in Switzerland, a country with a high number of patents in the field of nanotechnology.[11] Assuming that the usage of nanotechnological applications in the manufacturing sector is similar in comparable countries, the data presented here can therefore help to estimate the number of concerned companies in these countries.

The objective of this study was to create systematic information on the use of nanoparticles and their aggregates in Swiss industry, in order to create a basis to evaluate the health and environmental risk in Swiss companies. The study focused specifically on engineered nanoparticles. This comprised information on the quantity of nanoparticles used, current health and environmental protection measures and the number of potentially exposed workers.

METHODS

Nanoparticle definition

At the moment of the survey, a common definition of nanoparticles was not yet available. The definition of nanoparticles in the presented study is as follows:

a) All nanoparticles according to the ISO nomenclature TS 27687:2008(E).[1]

b) All particles with a mean diameter between 100 to 1000 nm were assumed to contain nanoparticles, unless there was concrete information about the size distribution and the stability of agglomerates.

c) Nanoparticle agglomerates or aggregates with unclear information on the potential liberation of primary particles.

d) The production of nanostructured surfaces with insufficiently described methodology that does not respond to the question whether particles or droplets can be released.

Statistical unit definition

In the year 2005 the Swiss insurance law statistics showed 428,908 Swiss companies, whereof 14,399 in agriculture, 63,353 in the manufacturing sector and 350,537 in the service sector (Commission for Accident Insurance Statistic - KSUV: Insurance portfolio; annex 1.3-1.5 of the five-year report 2008).

Study population

SUVA (Swiss National Accident Insurance Fund) is the biggest accident insurance in Switzerland; it is the compulsory insurance for most manufacturing companies (published data show 84.1% in the year 2005, unpublished data show a very similar percentage for 2007). For this study, the clients of SUVA were considered as being representative of the manufacturing sector in Switzerland. The 15.9% non-SUVA clients of the manufacturing sector were extrapolated assuming that they were similar to the SUVA clients. Of all the SUVA clients, 52.4% are manufacturing companies, 46.1% are in the service sector and 1.5% in the agriculture sector (KSUV). The selection of companies to be contacted was based on the total list of SUVA client for the year 2007 containing 91,804 companies.

Survey design and sampling

The survey was conducted in a stratified (layered) manner, expecting a different prevalence of nanoparticle usage in each economic branch. A total of 1,900 Swiss companies (1.77% of all SUVA-clients) were randomly selected from 21 layers, each consisting of one or several closely related economic branches. Companies with multiple productions sites were counted as one company summarizing all sites.

The random selection of companies in each of the layers was proportional to the size of the layers however, to avoid small sample sizes; the minimum was fixed at 50 companies.

To improve the quality of this survey, a panel of four experts reviewed the economic branches and excluded one layer from the mailing. This layer consisted mainly of administrative companies: Economic and technical offices, administrations, travel service and shops, governmental administration, post offices, employee placements and programs for temporary occupation of unemployed. This exclusion reduced the number of selected companies from originally 1,900 to 1,625 and the represented SUVA-clients from 91,804 to 78,559, a reduction of 14.4%. For the remaining layers such a definitive exclusion could not be made, even though about 30%-40% of the surveyed companies were expected to be in the service sector. The randomly selected companies represented finally 2.06% of the study population.

Extrapolation

The actual proportion of companies dealing with nanoparticles in each layer of SUVA clients was estimated by the proportion in the corresponding layer of the survey responses. Knowing that 84.1% of Swiss production companies are SUVA clients (KSUV), a direct

extrapolation was made to obtain estimates for all Swiss companies with an extrapolation factor of 1.19 applied to all layers in equal measure.

Of all the workers in Swiss manufacturing companies, 5.6% are employed by non-SUVA-clients (KSUV). Therefore the extrapolation for the number of workers applied a factor of 1.06 to all layers in equal measure.

Two complementary surveys

In order to assure the quality of the representative survey, two smaller surveys were realized investigating two special groups of companies.

a) Top-99 survey: The 99 largest companies employ 400,000 workers (21.9% of the workers insured by SUVA). However, only a few of these companies would be selected in a random sampling. Therefore an additional survey was conducted for the 99 largest companies that were not administration or financial institutions.

b) Targeted survey: several economic branches of different sizes have been merged into one statistical layer. This bears the potential that companies of a smaller economic branch are statistically underrepresented in the random selection within a layer.
195 companies were therefore selected in such underrepresented economic branches. This additional, targeted survey was not designed to be representative; instead it should fill an information gap and be informative for various Swiss agencies.

Data collection

For all three surveys a questionnaire that was harmonized with an unpublished version of the questionnaire of the German Federal Institute for Occupational Safety and Health, BAuA[(9)] was sent to the selected companies. The questionnaire requested information about the following topics:

- General company information and protection strategies: type of production and protection
- Material: Product name if available, particle composition; particle size
- Environment: Waste treatment and ventilation; yearly turnover; stock size
- Occupational hygiene: Type of protection used; number of workers related to the process and in the same production hall

An English translation of the questionnaire is available in the supplemental material.

The questionnaires were not anonymous. Instead, it was highlighted that all data would be transferred to their accident insurance company (SUVA) and that the investigators were contractually bound to strict confidentiality. The responding persons had to sign the questionnaire and state that they filled it to the best of their knowledge. The job function of the responding person was also registered.

Data validity check

All questionnaire data were checked for coherence before digitalizing (no contradictory answers, only comprehensible text information). Incomplete questionnaires or unclear descriptions were verified by contacting the company directly. To avoid misunderstandings, a random sample of companies, having stated in their questionnaire that no sub/µm particle applications were used, was contacted by phone to verify their response. The companies were asked specifically about nanoparticle applications, which were described in literature to be potentially in their domain. The minimal necessary sample size was calculated with the formula “binom.test” in S-Plus 6.2 (TIBCO Software Inc., Palo Alto, California) for the frequency of response observed.

Statistical analysis

The reported prevalence of nanoparticles in companies was compared to the response rate and the company sizes. The nanoparticle usage was shown extrapolated by Swiss industrial branch. Based on the same extrapolation, the types of nanoparticles and protection measures were presented. The information, whether a company had a nanoparticle application or not, served as depending variable, the company size as independent variable. Company sizes were clustered into four different size groups according to the Swiss federal statistical office (SFSO).[12]

A chi-square test (X^2-test) was applied to test for a difference between the companies receiving a letter and the companies answering to it. Additionally, the difference between the responding and the non-responding companies was analyzed with a Wilcoxon rank-sum (Mann-Whitney) comparing the difference in number of employees and with a X^2-test comparing the difference in the companies' zip-code as surrogate for the region. The zip codes were divided in five regional groups with equal number of sent letters. The difference between the response and non-response group was compared for each layer individually (Table 1). As the tests were made for nineteen layers, the rejection level was lowered to 1%. Stata (Version IC10, StataCorp LP, Texas, USA) was used for the Wilcoxon rank-sum test, Microsoft Excel (Version 2007, Microsoft Corporation, Redmond, Washington) for the X^2-tests.

Calculation of the confidence interval for the number of companies

For the calculation of the confidence interval of the number of companies with nanoparticle applications, the approach by Tillé and Graiss was applied, which uses Bernoulli

statistics.[13],[14] No confidence interval could be calculated for branches not reporting nanoparticle application. A detailed description of these calculations is available in the supplemental material.

Calculation of the confidence interval for the total number of potentially exposed Swiss workers

The number of workers among the SUVA-clients was extrapolated. The confidence interval of the number of workers was calculated as a normal stratified selection, according to Tillé and Grais.[13],[14] A detailed description of these calculations is available in the supplemental material.

RESULTS

Response rate and sample representativeness

In the layered survey the average response rate was 58.3% (947 out of 1,626 companies) and all twenty layers showed a response rate higher than 45%.

The response rates of the different language regions of Switzerland were similar: German-speaking 58.4% (702 out of 1,202 companies replied), French-speaking 56.4% (185 out of 328) and Italian-speaking 62.5% (60 out of 96). The response rates were 65.6 % (128 out of 195) for the targeted survey and 64.6 % for the Top-99 (64 out of 99).

The size distribution in the survey sample was compared to the SUVA-clients' size distribution (the 2006 SUVA client database) and all the production companies of the Swiss industry.[12] The proportions between the subsets were generally similar; differences can be explained with the study design. The X^2 test showed no significant difference between the group of sent questionnaires (selected sample) and the group of responses: Pearson chi2 = 6.4532, Pr = 0.092.

The questionnaires were signed by members of the management (54% of the responses), by administration personnel (17%), by health and security staff (10%), by human resources (4%), by workers (3%) and by environment/health specialists in less than 1%. In 12% of the questionnaires the job function was not declared.

Nanoparticle prevalence

Four of the companies stating that they have a nanoparticle application were excluded. A chimney sweep reporting soot, a carpenter reporting a particle application by error detected during a quality control call, a company reporting smoke of a miller process and a company using metal pieces that had a surface layer based on a nano-polymer without particle or droplet generation.

The following numbers of responses were taken into account: 947 in the main survey, 68 in the Top-99 survey and 131 in the targeted survey. Amongst these answers, the numbers of companies declaring a use of nanoparticles were 14, 7 and 20 respectively.

The fourteen companies declaring nanoparticle applications in the main survey reported that twenty-four workers in total dealt directly with nanoparticles or products containing nanoparticles. The distribution between the sexes of these workers was 94% men and 6% women.

Figure 2 shows that the response rate generally increased with the company size, however, the Top-99 companies showed a slightly lower response rate. The percentage of reported nanoparticle applications generally increased with the company size.

To verify the answer "no sub/μm-particle application", a random sample of fifty-nine companies (sample size necessary to reject false negatives at 95%) among the ones declaring that they did not deal with nanoparticles were contacted by phone: The interview partners were asked again about the usage of nanoparticles, this time specifically about applications

cited in literature to occur in this economic branch.[8] This answer was shown to be correct and not based on a misunderstanding for all fifty-nine companies.

Table I shows the results of the X^2-test, based on the zip code. There was no significant difference between responders and non-responders. Based on the size of the companies the difference was significant in one layer: public and private transportation.

Extrapolation from survey to SUVA and to Switzerland

Based on the number of companies and workers among the SUVA clients, the total number of companies and workers in Switzerland was extrapolated.

Table 1 shows the percentage of SUVA clients per layer dealing with nanoparticles. The responses of the main survey were extrapolated for all SUVA-clients, weighted according to the size of each layer. Among all SUVA-clients, 0.6% (95% confidence interval: 0.2% to 1.1%) or 493 companies (95%-CI: 122 to 864) deal with nanoparticles. The extrapolation for the Swiss industry calculates the corresponding number of companies dealing with nanoparticles to be 586 companies (95%-CI: 145 to 1,027).

Table 1 also shows the reported percentage of concerned workers among the SUVA client companies. An average of 2.5 workers per company dealt directly with nanoparticles or products containing nanoparticles, while 4.3 people worked in the same room. The number of workers in the layer "Trade" was interpolated from this average; the trade branch is basically composed of companies buying and reselling materials without manufacturing them. For all Swiss workers, this corresponds to 0.08% (95%-CI: 0.06% to 0.09%), or 1,309 workers (95%-CI: 1,073 to 1,545). A total of 0.2% (95%-CI: 0.17% to 0.22%) work in the same room as a nanoparticle application, which corresponds to 3,403 workers (95%-CI: 2,990 to 3,816),

Economic branches with nanoparticle applications

Figure 3 A) shows the distribution of companies dealing with nanoparticles among the economic branches of the Swiss production sector, Figure 3 B) the distribution of potentially exposed workers among the economic branches of the Swiss production sector, Figure 3 C) the amount of stocked material and Figure 3 D) the yearly turnover (usage rate) of nanoparticles. Four branches comprised the majority of reported nanoparticle users. The stock sizes as well as the yearly turnover ranged from grams to around one ton. No stock or yearly turnover of nanoparticles larger than 5,000 kg was reported in the main survey.

Stocks and turnovers of more than 5,000 kg were only reported in the additional surveys: The targeted survey reported two companies with a stock of around a hundred tons (organic pigments and carbon black). The targeted survey identified in two more layers nanoparticle applications: In the outside building construction and in the paper / print branch.

Type of nanoparticles

The reported nanoparticles were grouped into inorganic, organic and metallic. In the main survey, inorganic nanoparticles were mostly reported in the range of .1 to 5,000 kg with an average of 1,426 kg. Organic nanoparticles were reported to be used in the range of 10 to 1,400 kg, with an average of 365 kg. Only one company reported the usage of metallic nanoparticles in a liquid application of 500 l at 100 ppm.

The Top-99 survey showed results similar to the main survey. However, in the targeted survey two companies reported large amounts of nanoparticles: A paper production company using a $CaCO_3$-slurry (yearly turnover of several hundred tons of inorganic nanoparticles) and a paint-production company (one hundred tons of powder based organic pigments).

Protection measures

Figure 4 A) shows the types of measures used to protect workers in the companies that reported a nanoparticle application in the main survey. Among all the protection means, none showed a clear predominance: Personal protective equipment, technical measures as well as organisational measures were used. In the case of liquid applications, however, the integrated strategy to enclose a process completely was the most dominant protection type. Workplaces without any specific protection were only reported for liquid applications. Figure 4 B) shows the used environmental protection means. Most companies did not apply any special measure to protect the environment from potential nanoparticle release.

Only a small minority of the companies indicated the presence of nanoparticles in their products when sold to a customer.

DISCUSSION

This is the first representative study on the prevalence of industrial use of nanoparticles in an entire country. The companies selected included all industrial branches. The study design therefore allowed an estimation of the number of companies in Switzerland using nanoparticles, and of the number of Swiss workers potentially exposed at their workplaces due to the handling of nanoparticles or being present in the same hall as a nanoparticle application.

The here presented representative survey was designed to evaluate the percentage of concerned companies. It therefore complements the previously published targeted survey, which was a qualitative survey on users or producers of nanoparticles and which describes in more detail the types of particles used in Switzerland.[10]

The survey showed a usage of nanoparticles in only 0.63% of the Swiss manufacturing companies. This is a surprisingly low number, when considering that Switzerland has a rather long tradition of nanotechnology R&D and has one of the highest levels of patents and publications per capita.[11] Nanoparticle applications were most frequent in the industrial chemistry (21% of the companies of this branch). The automobile related industry, the electrotechnics and the general trade branches showed a smaller percentage of nanoparticle users, however, in terms of absolute numbers they are important branches and therefore the number of concerned companies is comparable to the industrial chemistry. The low amount of nanoparticle usage, mostly around a few kilos per year, suggests that these materials are only slowly introduced into industrial processes. The representative survey identified only companies using nanoparticles, but none that was producing them. Only one nanoparticle producing company was found in the targeted survey. This again suggests that the nano-market is still rather young.

The relatively low number of positive responses does not allow a detailed, branch-specific analysis of the occupational health and safety strategies. However, the overall message across all branches regarding the use of personal protection equipment corresponds well to the findings of the previous, more detailed qualitative pilot study. [10] This gives additional credibility to these observations. Only in a few companies some technical or organisational measures were applied. This suggests on one hand that the need for protection was recognized, but on the other hand, that more efficient, but less quickly introducible technical and organisational measures, were not (yet) implemented. Most companies still have considerable room to improve their protection strategies.

Several descriptive studies already investigated the occupational and environmental use of nanoparticles. Being non-representative they used very different approaches to gain

information: The UK's DEFRA study was based on a voluntary reporting system with a low participation rate: according to DEFRA (as of June 2009), during the 2-year trial thirteen data submissions were received, while the Woodrow Wilson consumer product inventory focused only on products that were commercially advertised as containing nanotechnology. The German BAuA-study focused on the use of nanoparticles in a targeted sample of companies[9] with a low response rate. Still, they showed similar types and quantities of nanoparticles per company as found in the here presented study for Swiss companies. A descriptive survey among French companies and laboratories estimated a low number of potentially exposed workers, however, as they look principally at companies producing nanoparticles, they estimate the percentage of potentially exposed workers to be 50%-80% per company.[15]

An Italian study tried to investigate the potential use of nanoparticles in industry and proposed an extrapolation based on the number of workers per economical branch for which an application was known.[16] As the study did not account for the prevalence of particles used in these industries, their result is to be considered as a maximal number of potentially exposed workers. The here presented study contrasts these results, showing that the percentage of companies using nanoparticles is very small.

A UK report estimated the number of workers potentially exposed to nanoparticles in the UK to be 2,000.[6] Knowing that the UK population is about ten times the Swiss population, this seems to be lower than the here presented 1,309 workers for Switzerland. However, the UK study focused only on novel nanotechnology industry and did not include other kinds of industry. The two studies' estimations are therefore not necessarily in contradiction.

The design of the here presented representative survey has some limitations. The total number of the extrapolation and some of the confidence intervals show the insecurity that several layers did not show any companies using nanoparticles. The outcome does not allow the distinction between “no application” and “only a few applications” in these layers. A bigger sample size would be necessary to achieve a more accurate result for these layers. However, the here provided estimates might be very useful for the design of future studies. Another limitation of the design is that two different assumptions could influence the results: Firstly the extrapolation from SUVA clients to all Swiss manufacturing companies (risk of overestimation) and secondly the fact that not all SUVA clients were manufacturing companies (risk of underestimation).

a) The extrapolation from SUVA clients to the total of Swiss production companies based on the assumption that the 84% SUVA-clients do not differ from the 16% non-SUVA clients. However, Swiss companies presenting specific dangers are forced by law to insure their employees against occupational accidents with SUVA. This might result in an over-proportional number of manufacturing companies being SUVA clients and therefore to a slight overestimation in the extrapolation. Unfortunately no federal statistics are available to clarify this issue.

b) The SUVA client list, even though aiming industrial production contains also non-manufacturing companies. One whole layer of administrative companies was excluded from the statistical selection. However, an estimated 30-40% of non-manufacturing companies remained in the survey. These non-manufacturing companies reduced the chances of a positive response in the survey, which might have lead to an underestimation of the nanoparticle usage.

The questionnaire did not mention specifically workers involved in the servicing of the plants. These workers might therefore not be included in the answers, even though they are potentially exposed to the nanoparticles remaining in an apparatus. None of the plastic producers/users declared usage of carbon black, despite the fact that this material was specifically mentioned in the introductory notes of the questionnaire as an example of sub/µm particles.

The recently adopted Swiss action plan on "Risk Assessment and Risk Management for Synthetic Nanomaterials 2006–2009" envisages risk research in the fields of nanotechnology which will allow not only the development of safer nanomaterials but also the creation of knowledge about the safer handling of these newly developed materials.[17] The collected data about the types of particles and applications may be used for research on prevention strategies and adapted protection means.

The information about the distribution between different industrial branches can help estimate the situation of nanoparticle usage in other countries than Switzerland. In a simple approach, this can be done by adapting for the stratification and the total size of the economic branches in other countries. Large companies were more likely to use nanoparticles (Figure 2), which could imply that an adjustment for company size might also be needed.

This survey did not identify any producers of nanoparticles. This confirms information obtained from trade organisations and federal agencies: there are only a handful of producers in Switzerland. As the number of potentially exposed workers in a nanoparticle producing company might be elevated [18], the expected number of potentially exposed workers could be higher in a country with more production of nanoparticles.

In conclusion, the here presented representative survey shows a small prevalence of nanoparticle applications, a small amount of used nanoparticles and a still limited number of

concerned workers in the Swiss industry. This knowledge might be interesting for quantitative risk-assessments and the development of worst-case scenarios. Only a handful of companies use a large amount of particles; in average this amount is very low. The small number of concerned Swiss companies indicates that there is still time to introduce necessary protection means in a proactive and cost effective way. However, to reflect the most recent trends, this information has to be continuously updated, and a large-scale or even a full inventory of the usage may be indicated.

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REFERENCES

1. **International Standard Organisation (ISO), ISO/TC 229** - *Nanotechnologies. Nanotechnologies - Terminology and definitions for nanoparticles.* ISO Central Secretariat, Geneva: ISO/TS 27687:2008(E). 2008.

2. **Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR):** *Opinion on the appropriateness of existing methodologies to assess the potential risks associated with engineered and adventitious products of nanotechnologies*, (SCENIHR/OO2/05). Brussels: SCENIHR, 2005.

3. **Meili, C., M. Widmer, F. Husmann, et al.:** *Synthetic nanomaterials. Risk assessment and risk management. Basic report for the action plan. German.* Federal Office for the Environment (FOEN), Federal Office of Public Health (FOPH), (Umwelt-Wissen Nr. 0721), Bern: 2007.

4. **National Institute for Occupational Safety and Health (NIOSH):** "Strategic Plan for NIOSH Nanotechnology Research and Guidance: Filling the Knowledge Gaps" (update 2008). [Online] Available at **http://www.cdc.gov/niosh/topics/nanotech/pdfs/NIOSH_Nanotech_Strategic_Plan.pdf** (Accessed April 21, 2009).

5. **Mueller, N.C. and B. Nowack:** Exposure modeling of engineered nanoparticles in the environment. *Environ Sci Technol* 42(12):4447-4453 (2008).

6. **Aitken, R.J., M.Q. Chaudhry, A.B.A. Boxall and M. Hull:** Manufacture and use of nanomaterials: current status in the UK and global trends. *Occupational Medicine-Oxford* 56(5):300-306 (2006).

7. **HM government**. *Response to the Royal Society and Royal Academy of Engineering Report: Nanosciences and Nanotechnologies: Opportunities and Uncertainties*. Lord Sainsbury of Turville, Minister for Science and Innovation. London: Department of Trade and Industry, 2005.

8. **Luther, W.:** *Technological Analysis, vol. 54: Industrial application of nanomaterials - chances and risks.* Düsseldorf: VDI-Technologiezentrum GmbH, 2004.

9. **Federal Institute for Occupational Safety and Health: BAUA - Germany:** Questionnaire on aspects of worker protection during the production and handling of engineered nanomaterials. Federal Institute for Occupational Safety and Health (BAUA, Germany). [Online] Available at **http://www.baua.de/nn_49456/en/Topics-from-A-to-Z/Hazardous-Substances/Nanotechnology/pdf/questionnaire.pdf** (Accessed April 21, 2009).

10. **Schmid, K. and M. Riediker:** Use of Nanoparticles in Swiss Industry: A Targeted Survey. *Environ. Sci. Technol*. 42(7):2253-2260 (2008).

11. **European Commission:** Nanosciences and nanotechnologies: Communication from the commission to the council, the European parliament and the economic and social committee: An action plan for Europe 2005-2009. COM(2005) 243 final. [Online] Available at **http://cordis.europa.eu/nanotechnology/actionplan.htm** (Accessed April 21, 2009).

12. **SFSO:** *Swiss Census of Enterprises 2007*. Neuchâtel: Swiss Federal Statistical Office, 2007.

13. **Tillé Y.:** *Theory of surveys: sampling and estimation from finite population.* French. Dunod: Paris., 2001.

14. **Grais B.:** *Statistical methods. French, 3e édition. Dunod: Paris, 2003.*

15. **Gaffet, E., D. Bloch, B. Gouget, et al.:** Nanomaterials – occupational safety: report of the AFSSET workgroup. French. 2006/006 ed. Maison-Alfort France: Agence Française de Sécurité Sanitaire de l'Environnement et du Travail (AFSSET), 2008.

16. **Boccuni, F., B. Rondinone, C. Petyx and S. Iavicoli:** Potential occupational exposure to manufactured nanoparticles in Italy. *J Clean Prod.* 16(8-9):949-956 (2008).

17. Federal Office of Public Health (FOPH), State Secretariat for Economic Affairs (SECO) & Federal Office for the Environment (FOEN): Swiss action plan on "Risk Assessment and Risk Management for Synthetic Nanomaterials 2006-2009". [Online] Available at **http://www.environment-switzerland.ch/div-4002-e** (Accessed April 21, 2009).

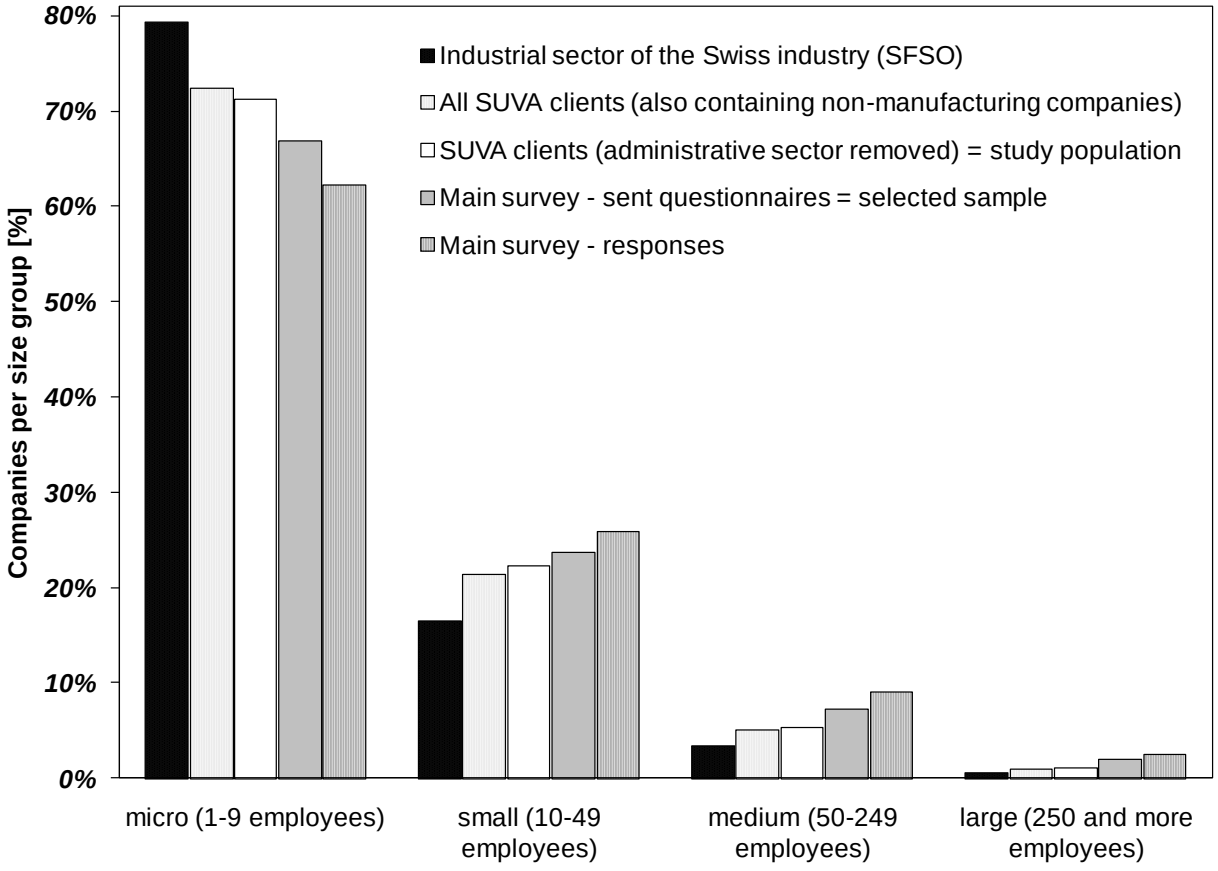

FIGURE 1. Company size distribution in each subset. All Swiss production companies (Swiss Federal Statistical Office, SFSO), all SUVA-clients (SUVA client database 2006), the SUVA-clients without the removed administrative sector, the layered survey sample and the responding subset.

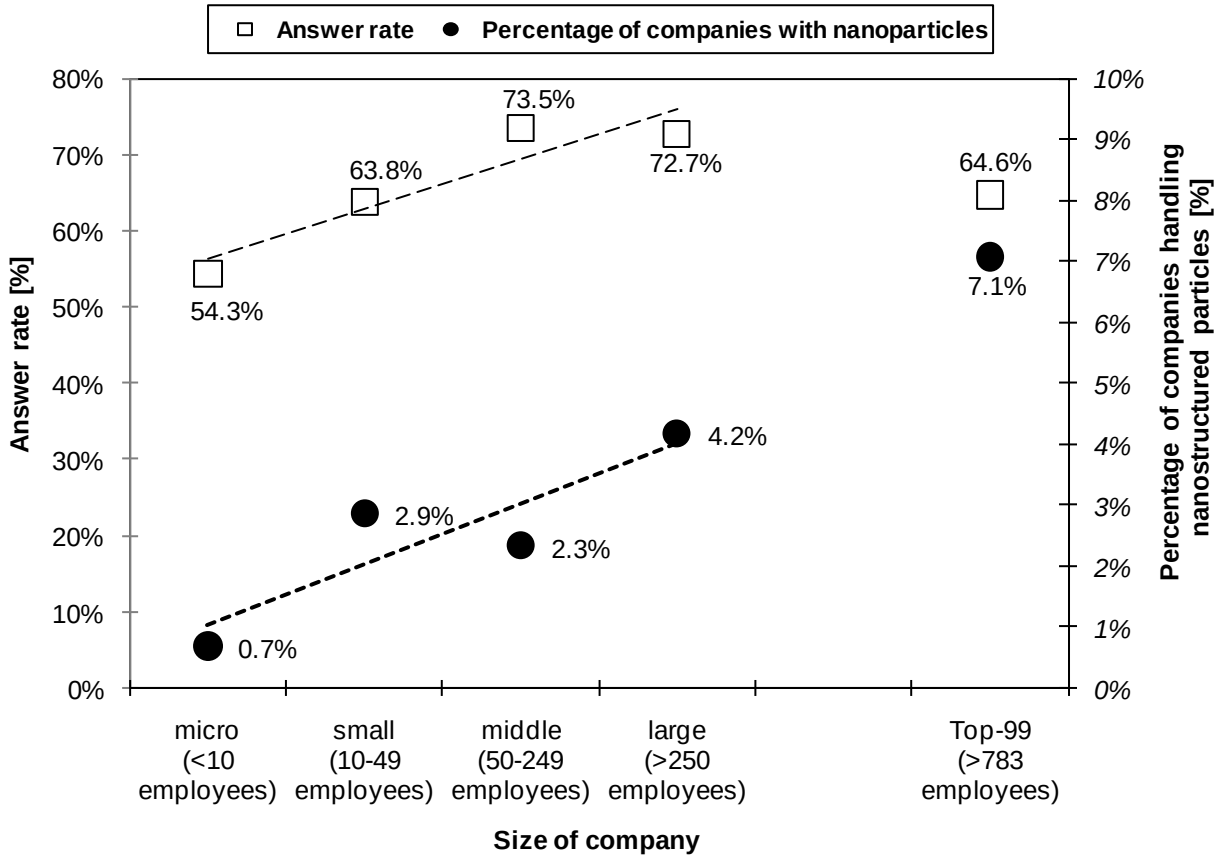

FIGURE 2. Response rate and percentage of companies reporting the use of nanoparticles compared to the company size. Both, the response rate and the percentage of companies dealing with nanoparticles increased with the company size (number of employees). The data of the additional survey Top-99 (ninety-nine largest Swiss companies) are in support of the tendency for more frequent nanoparticle applications in larger companies

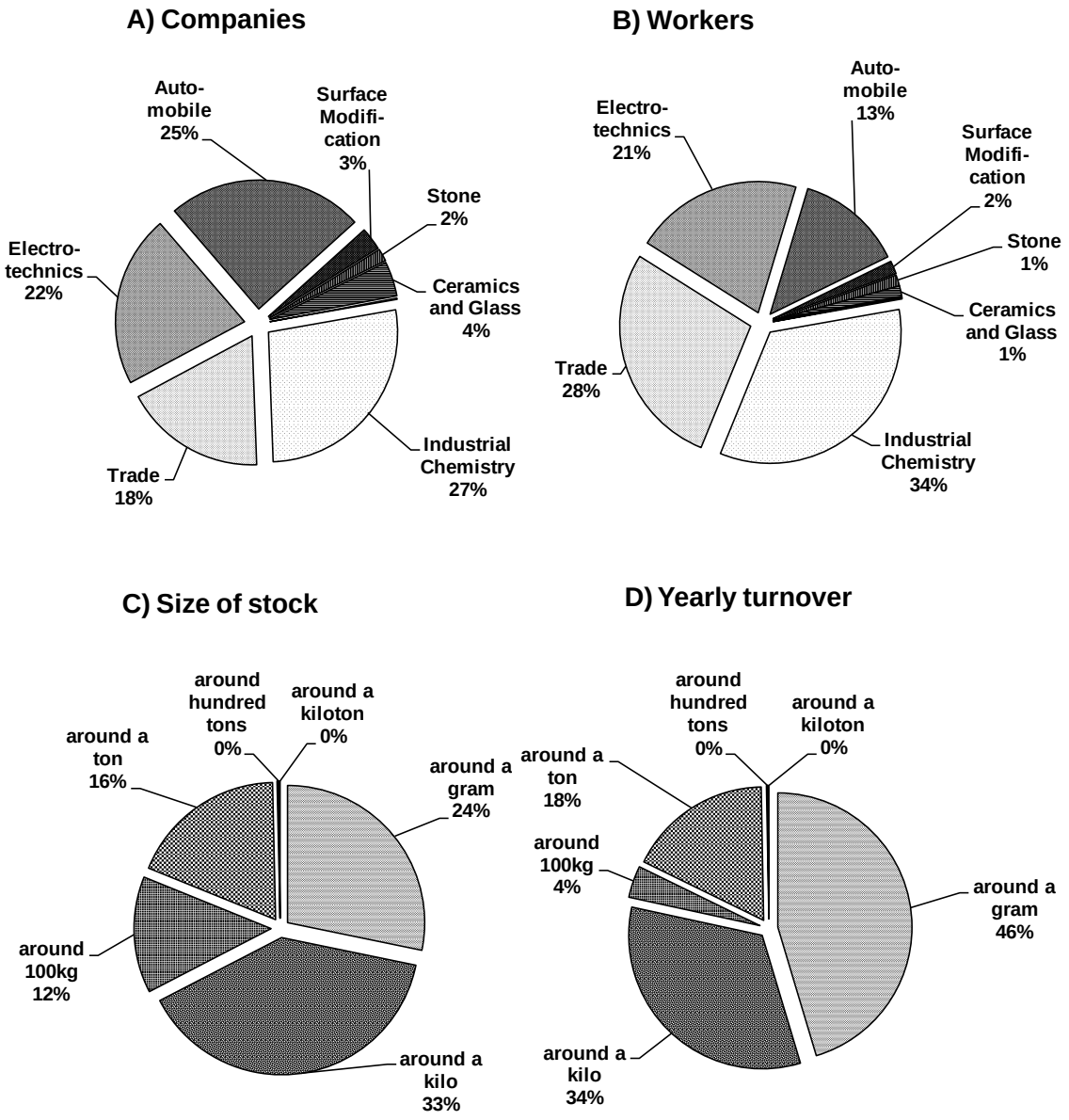

FIGURE 3. Distribution of companies with nanoparticle applications within the Swiss production sector. A) by company from the different branches, B) by number of workers in these branches. The frequency of the indicated stock size and yearly turnover of nanoparticles among the companies declaring a nanoparticle application is shown in C) amount of stocked material and D) yearly turnover (usage rate) of nanoparticles

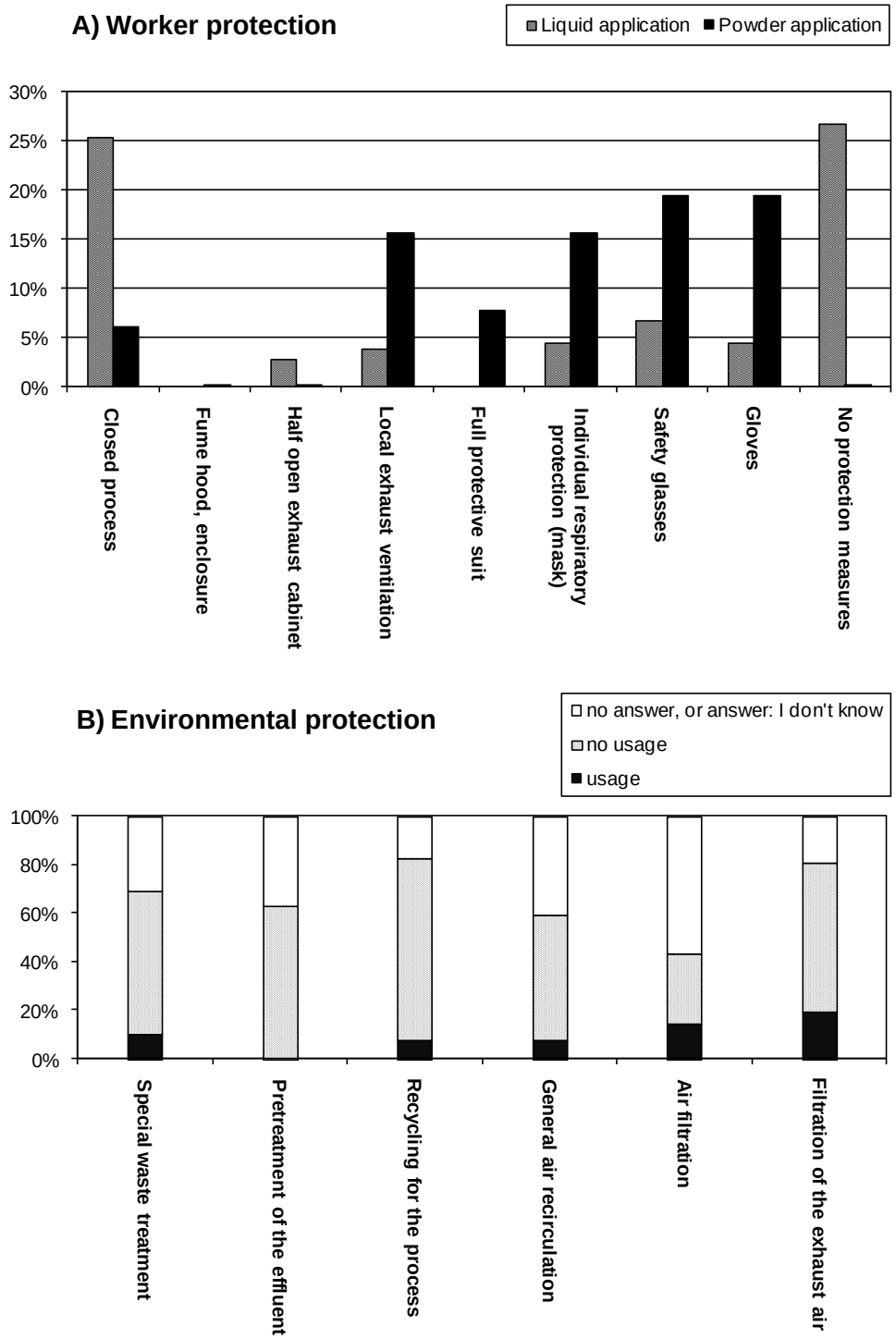

FIGURE 4. Measures to protect worker and environment. A) Types of worker protection measures used in the companies of the Swiss production sector. Frequency of companies using a type of protection divided in liquid applications and powder applications. No company used nano-powder without a protection. B) Types of environmental protection measures used in the companies of the Swiss production sector. The non-usage of all types of protection measures was predominant over the usage

TABLE I. Percentage of companies with nanoparticles and percentage of workers dealing with a nanoparticle application

Layers	SUVA[a]	Workers[b]	Questionnaires[c]	Answer rate	Nanoparticle companies[d]	Nanoparticle workers[e]	X^2 test zip code[f]	Wilcoxon test company size[g]
Chemical Industry	633	79,856	45	73%	21.21%	0.53%	0.32	0.54
Ceramics and Glass	334	7,035	49	63%	6.45%	0.23%	0.19	0.79
Surface Modification	366	6,761	43	60%	3.85%	0.30%	0.10	0.94
Stone	248	1,856	50	64%	3.13%	0.92%	0.59	0.09
Trade[h]	3,506	153,585	58	69%	2.50%	0.22%	0.17	0.29
Electrotechnics	5,524	195,689	92	57%	1.92%	0.13%	0.71	0.04
Automobile	11,283	100,282	186	50%	1.08%	0.16%	0.98	0.35
Building and Construction, Inside	16,301	132,186	265	48%	0.00%	0.00%	0.57	0.14
Metals	3,862	80,555	62	66%	0.00%	0.00%	0.71	0.41
Engine Construction	4,481	143,783	72	64%	0.00%	0.00%	0.07	0.05
Carpenter	5,670	50,335	95	56%	0.00%	0.00%	0.22	0.27
Paper and Printing	1,441	55,587	49	53%	0.00%	0.00%	0.10	0.43
Plastics or Polymers[i]	778	27,080	48	69%	0.00%	0.00%	0.72	0.28
Textiles and Leather	1,172	25,915	49	69%	0.00%	0.00%	0.04	0.61
Food and Agriculture	447	49,271	48	69%	0.00%	0.00%	0.46	0.83
Public Institutions and Administration	2,985	139,439	50	64%	0.00%	0.00%	0.07	0.71
Building and Construction, Outside	10,364	141,348	167	55%	0.00%	0.00%	0.13	0.09
Public and Private Transportation	5,666	129,295	93	60%	0.00%	0.00%	0.56	0.00*
Electricity	3,394	70,202	55	49%	0.00%	0.00%	0.26	0.02
Workplace integration for disabled	281	32,702	49	84%	0.00%	0.00%	0.63	0.44
Sum (numbers) /Average (%)	78,736	1,622,762	1,625	58%[j]	0.63%[k]	0.076%[k]	0.32	0.37

Footnotes:
[a]Number of companies represented in SUVA, [b]Represented number of workers covered by SUVA, [c]Number of sent questionnaires, [d]Companies dealing with nanoparticles, [e]Workers working with nanoparticles or products containing nanoparticles, [f]p-values of a X2 test for zip-code (5 regions), without correction for multiple comparisons. [g]p-values of a two-sample Wilcoxon rank-sum (Mann-Whitney) test for company size (number of workers), without correction for multiple comparisons. [h]Based on average of the other layers; [i]None of the plastic producers/users declared usage of carbon black, [j]Overall response rate; [k]Average weighted by layer.

Supporting Information

for

Nanoparticle Usage and Protection Measures in the Manufacturing Industry—A Representative Survey

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Number of pages: 13
Number of formulas: 22

This Supporting Information contains the description of the approach to statistical analyses for the results of the study "*Nanoparticle usage and protection measures in the manufacturing industry – a representative survey*" as well as an English translation of the questionnaires used (the questionnaires can be provided by the corresponding author in German, French and Italian). The corresponding numbers to the figure 1 of the manuscript are presented as well as a detailed description (translation) of the SUVA-code used for this study.

Contents

The questionnaires were created separately but then compared and adapted to the similar questionnaire of the German BAUA (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, www.baua.de).

Detail description of the approach to statistical analyses

Survey design and sampling

The survey was conducted in a stratified (layered) manner, expecting a different prevalence of nanoparticle usage in each economic sector. The definition of a single economic sector corresponded to an insurance risk class of SUVA. A total of 1900 Swiss companies (1.77% of all SUVA-clients) were randomly selected from 21 layers, each consisting of one or several closely related economic sectors. The software R version 2.2.1 was used to sample a representative selection according to each layers' defined sample size.

The random selection of companies (nh) in each of the layers was proportional to the size of the layers (Nh)

$$\frac{n_h}{N_h} = \frac{n}{N} \tag{1}$$

with n and N corresponding to the number of total questionnaires (n = 1900) and the number of total companies being clients of the SUVA (N = 91,804).

The number of selections n_h per layer was:

$$n_h = \frac{n \cdot N_h}{N} \tag{2}$$

.

In layers with only small economic sectors the numbers smaller than 50 have been replaced by 50.

$$m_h = \begin{cases} m_h = 0, if\ n_h > 50 \\ m_h = 1, if\ n_h \le 50 \end{cases} \tag{3}$$

.

A re-evaluation of the number of selected companies in the layers larger than 50 was necessary. We created the values n_{new} and N_{new} corresponding to the number of letters and number of total companies for the concerning layers with values n_h bigger than the minimal 50 to become:

$$n_{new} = n - \sum_{h=1}^{H} \left(m_h \times 50 \right) \text{ and} \tag{4}$$

$$N_{new} = N - \sum_{h=1}^{H} \left(n_h \times m_h \right) \tag{5}$$

Finally the size of the selection per layer (n_h^*) was given by

$$n_h^* = \begin{cases} n_h^* = \frac{n_{new} N_h}{N_{new}}, if\ m_h = 0 \\ n_h^* = 50, if\ m_h = 1 \end{cases} \tag{6}$$

To improve the quality of this survey, a panel of four experts reviewed the different economic sectors and excluded one layer from the mailing. This layer consisted mainly of administrative companies: Economic and technical offices, administrations, travel service and shops, governmental administration, post offices, employee placements and programs for temporary occupation of non employed. The exclusion of this layer reduced the number companies from originally 1900 to 1625 and the number of represented SUVA-clients from 91,804 to 78,559, a reduction by 14.4%. For the remaining 85.6% such a definitive exclusion could not be made, even though about 38% of the surveyed companies were not expected to be in the manufacturing, but in the service sector. The randomly selected companies represented finally 2.06% of the SUVA-clients.

Calculation of the confidence interval for the number of workers

The confidence interval for the extrapolation of the number of workers was calculated as for a normal stratified selection, according to Tillé[1] and Grais[2]. The responses' frequency in different layers was weighted by the size of the layers. Based on Tillé and Grais the confidence interval of the number of concerned workers in each layer was calculated as follows. The weighting f was calculated on N the total number of companies (SUVA clients) and n the number of selected companies:

$$f = \frac{n}{N} \tag{7}$$

The corrected variances of the population (S_y^2):

$$S_y^2 = \frac{1}{N-1}\sum_{k \in U}\left(y_k - \bar{y}\right)^2 \tag{8}$$

Where k is the selected element, U the total population and y the measured aspect. The corrected variances of the layer (S_y^2) can then be estimated without bias by (s_y^2)

$$s_y^2 = \frac{1}{n-1}\sum_{k \in S}\left(y_k - \hat{\bar{y}}_{sr}\right)^2 \tag{9}$$

where ($\hat{\bar{y}}_{sr}$) is the average of the measured elements weighted according to the stratification.
The variance of the estimator of the average ($\hat{V}(\bar{y})$) can be estimated by

$$\hat{V}(\bar{y}) = \frac{(1-f)}{n} s_y^2 \tag{10}$$

where $V\left(\hat{\bar{y}}_{SR}\right)$ is the estimator of the variances of each layer.

For this layered survey, the confidence interval of the total number of workers was calculated as follows: The weighting fh based on the Nh the total number of companies per layer and nh the number of selected companies per layer: fh = nh/Nh. The corrected variance of the population (S_y^2) was estimated by (s_y^2),

$$s_y^2 = \frac{1}{n_h - 1}\sum_{k \in S_h}\left(y_k - \hat{\bar{y}}_h\right)^2, \text{with} \, h = 1, \ldots, H \tag{11}$$

where k is the selected element, y the measured aspect and h the layer. The variance of the estimator of the average $V\left(\hat{\bar{y}}_{st}\right)$ was calculated by

$$V\left(\hat{\bar{y}}_{st}\right) = \sum_{h=1}^{H}\left(N_h \frac{N_h - n_h}{n_h} s_{yh}^2\right), \text{with} \, h = 1, \ldots, H \tag{12}$$

where (s_{yh}^2) is the variance of each layer and ($\bar{y}_{st}$) corresponds to the layers' average weighted in function of the layering.

Calculation of the confidence interval for the number of companies as a proportion.

The Yes/No-answer to the question asking whether the company had nanoparticle applications was considered to be a variable of Bernoulli (taking the value 1 if the character is present or 0 if it is not). The confidence interval for the response YES was calculated according to Tillé[(1)] and Grais[(2)]: The variance of the frequency was calculated in each layer, resulting in a confidence interval for each layer. For the sectors not reporting any nanoparticle application no confidence interval could be calculated. The confidence interval for the overall frequency was then calculated by weighting the different sizes of sectors,

$$p_1, p_2, \ldots, p_h, \ldots, p_k; p \tag{13}$$

The proportion of the characters in each layer and in the whole population is

$$f_1, f_2, \ldots, f_h, \ldots, f_k; f \tag{14}$$

where the frequency of the observation of an element X as a variable of Bernoulli is

$$p_h = \frac{1}{N_h} \sum_{s=1}^{N_h} X_{hs} \quad . \tag{15}$$

This is approximated using

$$f_h = \frac{1}{n_h} \sum_{s=1}^{N_h} x_{hi} \tag{16}$$

and the proportion p

$$p = \sum_{s=1}^{k} \frac{N_h}{N} p_h \tag{17}$$

will be estimated by f'

$$f' = \sum_{s=1}^{k} \frac{N_h}{N} f_h \quad . \tag{18}$$

The variance of the estimator f' is

$$V\{f'\} = \sum_{h=1}^{k} \left(\frac{N_h^2}{N^2} \cdot \frac{N_h - n_h}{N_h} \cdot \frac{p_h(1-p_h)}{n_h} \right), \tag{19}$$

the variance of the variable of Bernoulli within a layer h is

$$\sigma_h^2 = p_h(1-p_h)) \tag{20}$$

and the confidence interval C.I. (using the standard error SEM) is

$$C.I. = f_h \pm 1.96 * SEM_h = f_h \pm 1.96 * \sqrt{\frac{p_h(1-p_h)}{n_h}} \quad . \tag{21}$$

The variance of the estimator V* is estimated by

$$V^*\{f'\} = \sum_{h=1}^{k} \left(\frac{N_h^2}{N^2} \cdot \frac{N_h - n_h}{N_h} \cdot \frac{f_h(1-f_h)}{n_h - 1} \right). \tag{22}$$

References

1. **Tillé Y.:** *Theory of surveys: sampling and estimation from finite population.* French. Dunod: Paris., 2001.

2. **Grais B.:** *Statistical methods.* French, 3e édition. Dunod: Paris, 2003.

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English translation of the questionnaire

Questionnaire on nanoparticle use in Swiss industry

SWISS NANO-INVENTORY

22.01.2010

This questionnaire was made possible with the invaluable support of the following organizations:
SUVA, OFSP, OFEV, SECO and AFSSET (FR)

All the information provided by the companies participating in this survey will be treated in the strictest confidence.
IST will only share the identity of companies participating in this survey with SUVA.

Institute for Work and Health (IST)
IST is a foundation under Swiss private law, principally supported by the cantons of Vaud and Geneva. It is the only university institute in Switzerland devoted entirely to occupational health. IST has no inspection or monitoring function, though it is sometimes asked to give expert advice or to act as a consult in different fields of occupational health. Its missions are based around four activities: teaching, research, services and the promotion of occupational health.

IST is based in Lausanne and has over sixty employees (doctors, ergonomists, chemists, geologist, biologists, engineers, technicians, administrative staff and apprentices), many of whom are nationally and internationally recognized in their fields. IST is also a WHO Collaborating Centre for Occupational Health.

If you have any questions or require further information, please contact:
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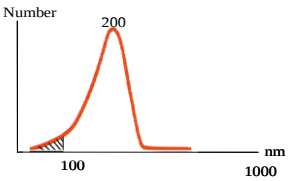
Project leader: Michael Riediker, PD Dr.sc.nat., IST, Rue du Bugnon 21, CH-1011 Lausanne

Sponsoring organizations: Swiss National Accident Insurance Fund (SUVA), Federal Office of Public Health (FOPH), Federal Office for the Environment (FOEN), State Secretariat for Economic Affairs (SECO) and French Agency for Environmental and Occupational Health Safety (AFSSET)

Please return your questionnaire to:
Institut de Santé au Travail (IST)
Rue du Bugnon 21
CH-1011 Lausanne

Introductory information

Why take a nano-inventory?	This questionnaire will enable IST to gather data on the use and application of nanoparticles in Switzerland and thus help to identify any eventual risks to health and the environment. It will therefore also prove useful in the preparation of a suitable program of safety at work and protection of the environment. At the European level, the European Commission - via its 'Nanotechnology Action Plan' – has suggested that member states carry out such inventories of the use and application of nanoparticles, as well as of any resulting exposure: http://cordis.europa.eu/nanotechnology/actionplan.htm
What exactly are nano-particles?	Nanoparticles are particles with a diameter of less than 100 nanometers (= 0.1µm) in at least two dimensions. Examples are: carbon black, metallic oxides (such as SiO_2, TiO_2, Al_2O_3, ZnO and Fe_2O_3/Fe_3O_4, etc.), nano-composites, carbon nanotubes, polymer dispersions, quantum-dots, etc. Nanoparticles may exhibit different properties from larger particles of the same chemical substance, often due to the larger total surface area available. These include different chemical, mechanical, optical, magnetic and biological properties. Nanoparticles have a strong tendency to agglomerate and aggregate. This process leads to a reduction in the total number of particles, but an increase in their size. However, the basic structure of the nanoparticles often remains the same. **This study will not take into consideration particles which are derived, for example, from thermal cutting, soldering, welding, metal grinding or foundry work. Likewise, motor exhaust gases will not to be taken into consideration.**
What are the potential dangers linked to nano-particles?	It is the specific chemical, mechanical, electrical, optical, magnetic or biological properties of these particles which make them so interesting for new technical applications, but also which raise questions about new risks to health and the environment. Based on recent animal and cell-based experimentation for certain types of nanoparticles, there are indications of potential hazards to human health. Currently, however, no definitive conclusions can be drawn from these few studies. For a satisfactory risk analysis, one must not only take into account a) the effects on health, but also, b) the number of people exposed, and c) the level and duration of exposure. The current expert consensus is that exposure to synthetic nanoparticles takes place mostly in the work place. The Swiss Nano-Inventory was specifically developed to evaluate this exposure.
Precisely why are we interested in particles measuring less than 1000nm?	This study aims to examine the use of all particles with a diameter of less than 1000 nanometers (<1µm). This is necessary because of typical particle size distributions. The accompanying graph shows a hypothetical distribution curve for particles with a 200 nm maximum (N.B.: depending on the type of nanoparticles, distribution curves can be completely different). A proportion of these particles has a diameter of smaller than 100 nanometers, and they are thus classed as nanoparticles. During a major industrial process, the proportion of these small particles can increase and become rather important. This is why we are not only interested in the particles themselves, but also in their size distribution. Graph: A hypothetical distribution of 200nm-sized particles 
In what applications can nanoparticles be used?	Synthetic or manufactured nanoparticles (including organic molecules) are often marketed in the form of nano-powders, liquid dispersions or pastes. Sometimes they are produced on site in specific production processes. Specific nanoparticle applications are well-known in the fields of cosmetics, food (animal feed, food additives for sport, food packaging), treating metallic surfaces, treating optical surfaces and paints. Other applications are still in the development phase. Nanoparticles are also being used in the fields of medicine and environmental protection. This list of uses is far from being exhaustive.
Data protection	This questionnaire was made possible by the invaluable support of: SUVA, FOPH, FOEN, SECO and AFSSET. **The identity of the companies participating will only be shared with SUVA**. The Institute for Work and Health has prepared a confidentiality agreement with SUVA. Federal government agencies will receive an anonymous report.
Additional information	Statement of the Swiss government to the Risks of Nanotechnology (EN) http://www.bafu.admin.ch/dokumentation/fokus/00118/index.html?lang=en Swiss Action Plan for 2006-2009 on the risks of synthetic nanoparticles (EN), http://www.bafu.admin.ch/chemikalien/01389/01393/01394/index.html?lang=en Report by the Royal Society on the ethical, medical and social challenges facing nanotechnology (EN), www.nanotec.org.uk/finalReport.htm Nanotechnology: Small matter, many unknowns? A brochure by SwissRe (EN), http://www.swissre.com/resources/31598080455c7a3fb154bb80a45d76a0-Publ04_Nano_en.pdf SUVA's standpoint on nanoparticles in the workplace (FR/GE), http://www.suva.ch/suvapro/branchenfachthemen/nanopartikel_an_arbeitsplaetzen.htm

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NANO-INVENTORY:
Basic information on the company

This questionnaire is supported by: SUVA, FOPH, FOEN, SECO and AFSSET. **All the information gathered will be treated in the strictest confidence. IST will only share the identity of companies participating in this survey with SUVA.**

Your company (institution or organization) has been chosen at random from SUVAs client list. Please return this questionnaire, even if you your company is not a manufacturing company or has no manufacturing facility in Switzerland. Please fill in this cover page and use questions 7 and 8 to elaborate.

Please do not write in this column.

General information about the company

1.	Company name:	1.
2.	Address (head office):	2.
3.	Contact person:	3.
4.	Number of staff (approx.):	4.
5.	Suva insurance no. (see envelope):	5. SUVA:
6.	What is your sector of activity?	6.
7.	Do you have a production site in Switzerland?	7. a) ☐ Yes b) ☐ No c) If 'yes', where? Postal code:
8.	Other remarks concerning this general information.	8.

Definition of nanoparticles/ultrafine particles: nanoparticles have two or more dimensions of less than 100 nanometers (= 0.1μm). In this survey, we are interested in all particles of less than 1000 nanometers (= 1μm). **Therefore, in this questionnaire, we use the terms "sub-micron particles" (particles <1μm) or sub/μm particles** (see the explanation sheet).

Does your company produce, use or release sub/μm particles?

9.	Are the sub/μm particles in your company:				
9.1.	manufactured?	9.1 a) ☐ yes	b) ☐ no	c) ☐ don't know	9.1a 9.1b 9.1c
9.2.	used?	9.2 a) ☐ yes	b) ☐ no	c) ☐ don't know	9.2a 9.2b 9.2c
9.3.	released by production processes (other than combustion or welding)?	9.3 a) ☐ yes	b) ☐ no	c) ☐ don't know	9.3a 9.3b 9.3c
9.4.	planned for future use?	9.4 a) ☐ yes	b) ☐ no	c) ☐ don't know	9.4a 9.4b 9.4c

If you do not use sub/μm particles, please indicate why:

☐ we do not need to use them ☐ health reasons ☐ don't know
☐ technical reasons ☐ financial reasons ☐ other; please specify

If you ticked "No" **to questions 9.1 to 9.3,** you can stop the questionnaire here and return it to the Institute for Work and Health.

I confirm that this questionnaire has been filled in good faith.

Name: Position: Signature:

Please return this questionnaire by the end of February 2007
to the Institut de Santé au Travail, Rue du Bugnon 21, CH-1011 Lausanne

XXX-XXXX.X

Basic information on the company using sub/µm particles

Please do not write in this column.

10. Which management level is responsible for safety with regard to sub/µm particles?	10. a) ☐ production or line manager b) ☐ safety or hygiene officer c) ☐ management d) ☐ other; please specify:	10.a 10.b 10.c 10.d
11. Does the company use a business sector solution? Please state the "solution's" name.	11. a) solution's number: or: name of business sector solution: (for example: no.7 Swiss Textile Federation) b) ☐ no, there is no business sector solution	11.a 11.b
12. Is there an occupational physician or an occupational hygienist in your company?	12.1 occupational physician a) ☐ yes b) ☐ no c) ☐ external 12.2 occupational hygienist a) ☐ yes b) ☐ no c) ☐ external 12.3 safety engineer a) ☐ yes b) ☐ no c) ☐ external 12.4 safety officer a) ☐ yes b) ☐ no c) ☐ external	12.1a 12.1b 12.1c 12.2a 12.2b 12.2c 12.3a 12.3b 12.3c 12.4a 12.4b 12.4c
13. How frequently are employees informed of the potential dangers sub/µm particles?	13. a) ☐ with every order b) ☐ approx. 1x per week c) ☐ approx. 1x per month d) ☐ approx. 1x per year e) ☐ other; please specify: f) ☐ never	13.a 13.b 13.c 13.d 13.e 13.f
14. Does the technical data sheet description of your product contain information about sub/µm particles?	14. a) ☐ yes b) ☐ no c) if 'yes', which ones?	14.a 14.b 14.c
15. Which sub/µm particles do you use? Please give all available information.: Example: process: "varnish production" or "varnishing", final product: "varnish" or "furniture surfaces". If you use more than three types sub/µm particles, please use the back of this sheet.	15. a) product name 1: b) base substance: c) process name: d) final product: e) average particle size: f) product name 2: g) base substance: h) process name: i) final product: i) average particle size: k) product name 3: l) base substance: m) process name: n) final product: o) average particle size:	15.a 15.b 15.c 15.d 15.e 15.f 15.g 15.h 15.i 15.j 15.k 15.l 15.m 15.n 15.o
16. Storage 16.1. What quantity of sub/µm particles do you have in stock? (approx.): 16.2. What quantity is delivered to you by your suppliers (per delivery) (approx.)? 16.3. How often does your supplier deliver? 16.4. How often do you deliver to your clients? 16.5. What quantity do you deliver to your clients (per delivery)?	If you have more than one type of particle, please specify answers for each one of them by using the back of this sheet or an additional sheet. 16.1 a) ☐ g b) ☐ kg c) ☐ 100kg d) ☐ t e) ☐ 100t f) ☐ kt g) ☐ other; please specify 16.2 a) ☐ g b) ☐ kg c) ☐ 100kg d) ☐ t e) ☐ 100t f) ☐ kt g) ☐ other; please specify 16.3 a) ☐ per week b) ☐ per month c) ☐ per year d) ☐ other; please specify 16.4 a) ☐ per week b) ☐ per month c) ☐ per year d) ☐ other; please specify 16.5 a) ☐ g b) ☐ kg c) ☐ 100kg d) ☐ t e) ☐ 100t f) ☐ kt g) ☐ other; please specify :	16.1a 16.1b 16.1c 16.1d 16.1e 16.1f 16.1g 16.2a 16.2a 16.2c 16.2d 16.2e 16.2f 16.2g 16.3a 16.3b 16.3c 16.3d 16.4a 16.4b 16.4c 16.4d 16.5a 16.5b 16.5c 16.5d 16.5f 16.5g

Please return this questionnaire by the end of February 2007

to the Institut de Santé au Travail, Rue du Bugnon 21, CH-1011 Lausanne

Do you have several processes? If so, please number your pages: No:

Manufacturing process (process description)

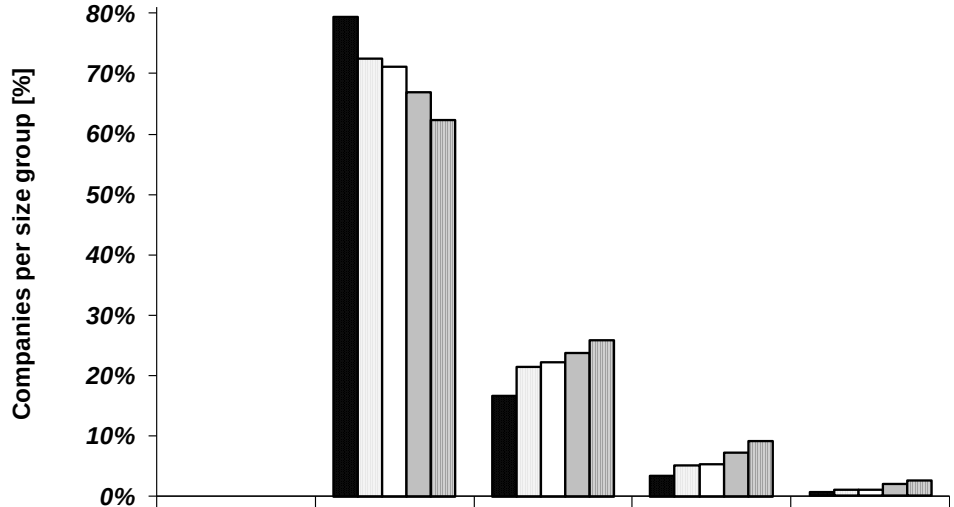
Please photocopy and number this page for each different process involving sub/µm particles. If you use more than one type of sub/µm particle in a specific process, then please simply state the types of particles which you use on the back of this sheet.

		Please do not write in this column.
17. Process description, e.g. manufacturing photographic paper X.	17.	17.
18. Type of particles used in the process (please also indicate your own production)	18. a) product name: b) base substance: c) average particle size: [nm]	18a 18b 18c
19. In which form do the sub/µm particles in your process exist?	19. a) ☐ powder b) ☐ dispersion/liquid c) ☐ other; please specify	19a 19b 19c
20. What is the approximate quantity produced via this process per year?	20. [kg/year] or [liters/year] with concentration [g/liter]	20.
21. What type of packaging does the supplier use for delivery?	21. a) ☐ barrel b) ☐ tank c) ☐ solid state d) ☐ bag e) ☐ big bag f) ☐ other; please specify	21a 21b 21c 21d 21e 21f
22. Is there an intermediate storage phase for particles during the process?	22. a) ☐ yes b) ☐ no	22a 22b
23. Are particles poured from one storage medium to another?	23. a) ☐ yes b) ☐ no	23a 23b
24. Process duration and frequency 24.1. How often does the process take place? 24.2. How long does the process take?	24.1 a) ☐ per year b) ☐ per week c) ☐ per month d) ☐ other; please specify 24.2 a) ☐ minutes b) ☐ hours c) ☐ days d) ☐ other; please specify	24.1a 24.1b 24.1c 24.1d 24.2a 24.2b 24.2c 24.2d
25. Means of protection: 25.1. Which type of protection measures have you chosen?	25.1 a) ☐ this is a confined process b) ☐ extraction hood/fume cupboard c) ☐ semi-open environment or cabin d) ☐ open environment with at source air extraction e) ☐ all-over body protection f) ☐ mask g) ☐ goggles h) ☐ gloves i) ☐ none j) ☐ other; please specify	25.1a 25.1b 25.1c 25.1d 25.1e 25.1f 25.1g 25.1h 25.1i 25.1j
26. Work space ventilation 26.1. Is the air recycled? 26.2. If 'yes', what % is recycled? 26.3. If 'yes', is the air filtered? 26.4. If 'yes', what is the rate of deposition (or class of filter)?	26.1 a) ☐ yes b) ☐ no c) ☐ don't know 26.2 a) % b) ☐ don't know 26.3 a) ☐ yes b) ☐ no c) ☐ don't know 26.4 the rate of deposition is: % (or the class of filter is:)	26.1a 26.1b 26.1c 26.2a 26.2b 26.3a 26.3b 26.3c 26.4
27. How many people are directly involved in the manufacturing process or are stationed in the same work area?	27. a) number of persons involved in the process: b) number of persons in the same work space: c) of which approx. % men and % women	27.a 27.b 27.c
28. Do you know the average exposure to particles in the workplace? (please give known values)	28. a) ☐ no b) ☐ alveolar dusts -a: [µg/m^3] c) ☐ inhalable dusts -i: [µg/m^3] d) ☐ number de particles: [number/cm^3] e) ☐ other; please specify:	28.a 28.b 28.c 28.d 28.e
29. Effects on the environment: 29.1. Are waste products from this process specially treated? 29.2. Is waste water from this process specially treated? 29.3. Does your company recycle materials? 29.4. Is air leaving the manufacturing process recycled? 29.5. What is the rate of deposition in the air recycling filters?	29.1 a) ☐ yes b) ☐ no c) ☐ don't know d) ☐ this process produces no waste products 29.2 a) ☐ yes b) ☐ no c) ☐ don't know d) ☐ this process produces no waste water 29.3 a) ☐ yes b) ☐ no c) ☐ don't know 29.4 a) ☐ yes b) ☐ no c) ☐ don't know 29.5 a) the rate of deposition is: % b) ☐ outgoing air is not filtered c) ☐ don't know	29.1a 29.1b 29.1c 29.1d 29.2a 29.2b 29.2c 29.2d 29.3a 29.3b 29.3c 29.4a 29.4b 29.4c 29.5a 29.5b 29.5c

Please return this questionnaire by the end of February 2007

to the Institut de Santé au Travail, Rue du Bugnon 21, CH-1011 Lausanne

Additional information to Figure 1:



	number of companies (100%)	micro (1-9 employees)	small (10-49 employees)	medium (50-249 employees)	large (250 and more employees)
■ *Industrial sector of the Swiss industry (SFSO)*	*72,540*	*79.4%*	*16.6%*	*3.4%*	*0.6%*
□ *All SUVA clients (also containing non-manufacturing companies)*	*91,592*	*72.5%*	*21.4%*	*5.1%*	*1.0%*
□ *SUVA clients (administrative sector removed) = study population*	*78,559*	*71.2%*	*22.3%*	*5.4%*	*1.1%*
▨ *Main survey - sent questionnaires = selected sample*	*1,616*	*67.0%*	*23.8%*	*7.2%*	*2.0%*
▨ *Main survey - responses*	*943*	*62.4%*	*26.0%*	*9.1%*	*2.5%*

Numbers to "FIGURE 1. Company size distribution in each subset. All Swiss production companies (Swiss Federal Statistical Office, SFSO), all SUVA-clients (SUVA client database 2006), the SUVA-clients without the removed administrative sector, the layered survey sample and the responding subset.

A chi-square test (X^2 test) was applied to analyze the similarity of the size proportions between the group of sent questionnaires (selected sample) and the group of responses. Pearson chi2 = 6.4532, Pr = 0.092. Cramér's V = 0.0502. The differences between the other groups can be explained with the study design.

Additional information to the SUVA-Code

Short definition	*SUVA-Code*	*Detailed definition (translated!)*
Building and Construction, Inside	01A	cement / lime / gypsum factories and mines
	01B	sand and gravel mines, concrete plants, bituminous mix
	02A	cement goods manufacturer
	44D	painter and plasterer
	45B	floor layers
	45BA	floor layers
	45BB	floor layers, interior decoration, sewing
	45D	cleaning services, building maintenance
	45G	companies for sanitary installations, heating, air-conditioning and ventilation systems, plumbers
	45GC	chimney sweeper business
	45GD	tank inspection / revision
	45GE	installation companies
	45GF	plumber
	45GG	installation companies, plumbers
	45GH	plumber and roofer
	45GK	installation companies, plumbers with roofer
	45L	assembly companies
	45M	wall panels, paving tiles, pottery, thermal and noise insulation work
Ceramics and Glass	06A	ceramics and glass
	06AA	coarse ceramics
	06AB	fine ceramics
	06AC	glass and glass products
	06AD	glass workshop
Metals	10M	metallurgy
	10MA	metal producer
	10MB	plastic forming of metals
	10MC	foundry for metals, without sand moulds
	10MD	foundry for metals, with sand moulds
	11C	steel and metal construction, apparatus engineering , metalworking shop, forging
	11CA	smith, metalworker
	16B	manufacturer of iron, sheet metal and metal
	16BA	tinsmith industry
	16BB	metal goods, metal packaging, metal stamping
	16BC	wire products
	16BD	locking technology, cutlery and arms
Engine Construction	11CB	apparatus engineering and construction metal works
	11CC	production, assembly and repair of net curtains and shutters
	11CD	production of tubular steel furniture and other light metal tube products
	13B	construction of machines and equipments
	13BA	production of components for mechanical engineering
	13BB	mechanical engineering, equipment construction
	13BC	assembly and repairs of products from mechanical engineering industry
Surface Modification	16C	surface technology
	16CA	varnish, lacquers
	16CB	electroplating
	16CC	thermal surface technology
Carpenter	17S	sawmills and timber industry
	18S	millwork
Paper and Printing	22D	production of paper, cardboard, pulps
	25C	paper, foil, cardboard and corrugated cardboard processing
	25CA	paper, film and foil processing
	25CB	cardboard manufacturer
	25P	media and printing
	25PG4F	sound studio / film studio
	25PG4K	video rental
	25PG4L	photographic laboratory
	25PG4P	production of planning, filing and presentation materials
	25PG4S	design of signs and advertisement
	25PG4V	pre-press and print forme manufacture
	25PG4W	book producers / packagers
	25PGO	printing house
Plastics or Polymers	23C	plastics production and processing
	23CA	plastics processing - sections, unfinished form
	23CB	plastics processing - shaped pieces
	23CC	mechanical processing chipping / non chipping plastics and semi-finished products
Textiles and Leather	26A	leather production and interior decoration
	26AA	interior decorating / interior design
	26AB	shoe manufacture, leather and fur industry

	27T	textile and clothing industry
	27TA	textile fibre processing, production of yarn and fabric
	27TB	yarn and technical textiles (without textile fibre processing)
	27TC	clothing industry
	27TD	synthetic fibres manufacture
	30B	laundry, dry cleaning
Chemical Industry	32A	production of basic and fine chemicals, pharmaceutics and cosmetics
	32F	chemical-technical production
Food and Agriculture	35H	slaughterhouse
	35I	butcher's shop
	35N	food industry
	37D	tobacco industry / cigarettes and cigars manufacturers
Stone	38S	sculpture's workshop, rock sawmill
Public Institutions and Administration	40M	public administration
	40MA	work for self-supply
	40MC	hospitals, homes
	40MD	administration management, schools
Building and Construction, Outside	41A	construction
	42B	forestry
	44E	roofing and facade cladding
Public and Private Transportation	46A	federal train company
	46H	sleep and dining wagon company
	47B	licensed train company
	47D	tramways and trolleybus company
	47E	cable cars and ski lifts company
	48A	boat company
	49A	road transportation company
	50A	air transportation company
Trade	52A	trading and stocking businesses
	52AG	general trade
	52AH	steel and semi-finished metal trade
	52AK	trade with construction material and wood
	52AL	petrol and fuel trade
	52AM	farming cooperation
	52AN	stock
	52AR	wholesale
	52D	recycling company
	52T	beverage manufacture and trade
	52TA	preparation of beverages
	52TB	brewery
	52TC	beverage trade and stock
Electricity	55A	power plant and power distribution company
	55C	cable and overhead line construction
	55D	electrical installation
	56B	electric and gas utilities
Workplace integration for disabled	71A	workshop for the handicapped
Automobile	13D	repair workshop for cars and farming machines
	13DA	repair workshop for light cars
	13DB	repair workshop for heavy cars
	13DC	repair workshop for farming machines and construction site machines
	13DD	repair workshop for motorcycles and scooters
	13E	car coachworks, paintwork and tinsmith's workshop
	13EA	workshop for car bodywork and coach building
	13ED	repair workshop for bodywork (cars)
Electrotechnics	15DA	goods of information technology, micro technology, medicinal technology, watches and jewelry
	15DB	reparation of information technology, micro technology, medicinal technology, watches and jewelry
	15DC	electronic technology manufacture
	15DD	repair and maintenance services for electrical engineering