New Risks in OHS with Focus on Selected Nanotechnological Workplaces

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Nanotechnology is part of a group of “new risks” that have not been addressed at all from the point of view of the occupation health and safety (OHS). The basic precondition for risk management is based on sufficient information about nanomaterials used i.e. their behavior and properties, exposure to toxic effects etc. Because of the many uncertainties that nanomaterials possess, the application of the standard risk management approach is ineffective. For this reason, Control Branding (C) methods are gradually introduced and are used to assess exposure when exposure limit values are not set.

Selected workplaces (engineering, agricultural production, human activities and food production) were selected as part of the article and measurements (Testo DiSCmini device) confirming the main sources of nanomaterial production in anthropogenic industrial production or in operations of human activity. Subsequently, they identified the way they were distributed in the technological space and found the factors in this space that played a role in changing the concentration or properties of the nanoparticles and their distribution. In the group of tested workplaces, the highest risk was found in the smelting and casting of aluminum, and copper soldering in the engineering production. Elimination of the risk of nanoparticle scarring is generally not possible in practice, and it is therefore necessary to define and implement such preventive measures that will provide the required protection for employees.

Keywords: Risk, nanomaterials, workplace, measurement, nanosecurity, precautionary principle.

1. Introduction

Nanoparticles are commonly found in the environment independently of human activities (erosion, products of wood fires, dissociation of substances, sea water, volcanic gases, etc.) (Klouda et al., 2016). Human activity affects the production of nanoparticles as industrial waste (steelworks, ironworks, mining of raw materials, ceramic industry, etc.) or waste caused by transport (Warheit,2018). Nanoparticles are also intentionally manufactured as a product of new technologies (Act no. 199/2002). Intentionally produced particles include “engineering nanoparticles“ which are mainly materials on a carbon base (fullerenes, graphite oxide, graphene, SWCNT, MWCNT), materials on a base of nanometals and their oxides (TiO_2, ZnO, Al_2O_3), dendrites, composite nanomaterials, quantum dots, etc.

Admittedly, nanoparticles are suspected to negatively affect human health (Pietroiusti et al., 2014). Many research studies on humans as well as animal models indicate their many-sided effect on the physiology of living organisms (Tetley, 2007). Consequently, it is important to not underrate the effect of nanoparticles and to continually pay attention to the technological waste of anthropogenic activities. The idea is to search for a source of nanoparticles and to find

Proceedings of the 29th European Safety and Reliability Conference.
Edited by Michael Beer and Enrico Zio

ISBN: 981-973-0000-00-0 :: doi: 10.3850/981-973-0000-00-0 esrel2019-paper

and apply technological measures while also using personal protective devices for workers (citizens, residents) in order to minimize their exposure (Watson et al., 2017). For this reason, it is necessary to obtain data from workplaces (e.g. engineering, food processing, agricultural) as well as from other human occupations like leisure activities, smoking, shooting, grass-cutting, etc. (Ding et al., 2017; Duarte et al., 2014). Therefore, the research project of the Occupational Safety Research Institute Prague, v.v.i., no. VUS4_02_VÚBP "Evaluation of risk of nanoparticles at workplaces and a potential for prevention" (institutional support of the Czech Ministry of work and social affairs, duration of project 2018-2020) has been prepared and focuses on finding and validating, by measurement, the main sources of nanomaterial production, either in industrial manufacture or in other activities related to human activities.

The second step will be to identify the method of their distribution in technological space and pinpoint the factors affecting a change in their concentration or in their qualities. After the data is processed, and after consultation with factory managements, technological and organizational measures will be proposed for the reduction of contact with nanoparticles. This should decrease the consequences of their toxicity, which is affected by a change in the physico-chemical dimensions of surface, i.e. an increase in chemical reactivity.

Examples of selected premises recently evaluated:

- Engineering production;
- Quarrying of stone;
- Manufacture of construction products;
- Electric company – manufacture of electric products;
- Manufacture of food products;
- Repair of motor vehicles;
- Breweries;
- Forestry activities;
- Agriculture;
- Construction of non-residential buildings;
- Other human activities (smoking, dental hygiene, marksmanship, car driving, city walking).

2. Main Techniques of Measurement

At present, there are two basic methods of measuring suspended particles in the work environment. These are indirect gravimetric determination after the capture of aerosol particles on a filter, and direct continuous measurement. For the purpose of our basic evaluation and for the sake of speed of measurement, we used the Testo DiSCmini device, which measures the number and size of nanoparticles in a volume unit.

3. Measurement Findings and Preliminary Conclusions

As regards purity of the workplace environment (concentration of nanoparticles), the best outcome was found in the modernized semi-automatic bakery, in the climatized cabin of the new tractor, and in the new combine harvester.

A low and a stabile concentration of nanoparticles was registered in the cowshed with dairy cows (30,000 $\#\cdot cm^{-3}$, mean 35 – 40 nm); on the contrary, an increased concentration was recorded in the horse stable, especially during the grooming of horses.

In the engineering factory where steel components for wood grinders are manufactured, the welding cabin was found as the biggest source of high concentrations of nanoparticles. CNC machines for cutting and firing materials (laser, water ray, flame, band and circular saw) demonstrated the highest concentrations during laser cutting (Bařinová et al., 2018).

The high concentrations of nanoparticles at ca. 1,000,000 $\#\cdot cm^{-3}$ were recorded in the production room where aluminum is melted and cast. Nanoparticles were found with a small diameter (25 – 35 nm), where the risk of penetration into the cell is increased. A particle concentration up to 500,000 $\#\cdot cm^{-3}$ was registered in the hall where copper bunched wires for electromotors are soldered. In both these cases, an increased toxicity of nanoparticles is expected given the chemical composition – aluminum and its oxide and oxyhydroxides, copper and its oxides.

A risk of increased concentrations was demonstrated in the factory for the preparation of mortar mixes during the bagging process and measuring out to the closed technological line.

The positive impact of sprinkling water was confirmed on the concentration and dimension of nanoparticles released into the work environment during stone cutting with different technologies (band saw, frame saw) in comparison to dry treatment (milling). During the water sprinkling, the concentrations reported were 83,000-142,000 $\#\cdot cm^{-3}$, while during milling, the concentrations reached up to 597,000 $\#\cdot cm^{-3}$ (Frišhansová et al., 2018).

Concentrations of particles were registered at the busy intersection "U Bulhara" in winter (-1 °C) and in summer (30-36 °C) during the same level of traffic (3-4). The average concentration of particles in the summer was one-quarter the size of the winter measurement, while the size of the particles was comparable on both occasions (40-50 nm). During the winter season, a measurement also took place at an intersection in Ostrava in similar traffic conditions as in Prague, but the values found were twice as high as in Prague (Sirovátka, 2018).

Balanced values of the nanoparticle concentrations 70,000-80,000 $\#\cdot cm^{-3}$ and sizes 45-55 nm were registered in the assembly rooms of the Subaru services. Recorded values there were comparable to the values registered at the winter measurement on the busy intersection in Prague.

During hay gathering and baling, the operator outside the closed cabin of the machine is less endangered than the operator harvesting the barley and standing near the harvester (400,000-800,000 $\#\cdot cm^{-3}$).

Measurements were carried out in the large-scale breeding environment of male and female turkeys. The turkeys are kept in a windowless structure equipped with ventilation. The turkeys responded calmly to the entrance of the measurement technicians. The basic nanoparticle concentration was higher than in the hall with the turkeys and reached the order of 60,000 $\#\cdot cm^{-3}$. The number of nanoparticles during the presence of the measurement technicians in the hall increased to 120,000-140,000 $\#\cdot cm^{-3}$. The value of the particles in the hall then stabilized, and before leaving it was 60,000 $\#\cdot cm^{-3}$. Particles consistently reached the same 25 nm values.

4. Illustration of the Findings from the Field Measurements

Examples from the detailed processing of findings in the electric products manufacture (Chapter 3.1), from the measurement in the 2-line cowshed (Chapter 3.2) and in the field measurements in the engineering plant (Chapter 3.3).

4.1 The Electrical Products Manufacture (Illustration of the Detailed Processing of our Findings in Measurement)

In the hall where the smelting of aluminum takes place (Fig. 1) the high concentration of nanoparticles was found – 180,000 $\#\cdot cm^{-3}$ (Fig. 3, see below). During the aluminum tapping the values found were up to 800,000 $\#\cdot cm^{-3}$ and the drop in nanoparticles diameter by 10nm, the fall from the stabilized state 32-35 nm to 25 nm (Fig. 4, see below).

Fig 1. Aluminium smelting and casting [own study]

4.2 Two-line Cowshed with Dairy Cows (Illustration from the Detailed Processing of our Findings in Measurements)

In the cowshed the hay from the tested meadow is used as a fodder and as a bedding for cows (Fig.2). During the milking, measurements were done while walking in the central passage between the cows (4times up and down), concentrations of nanoparticles were stabile 30,000 $\#\cdot cm^{-3}$ (Fig. 5, see below), so were the size of nanoparticles 35 – 40 nm (Fig. 6, see below). The same values were found in the store of hay and clover. Only during the hay forking the concentrations grew transitorily by 20,000 $\#\cdot cm^{-3}$ from 30,000 $\#\cdot cm^{-3}$ and the size of particles grew too.

Fig. 2 The 2-line crowshed

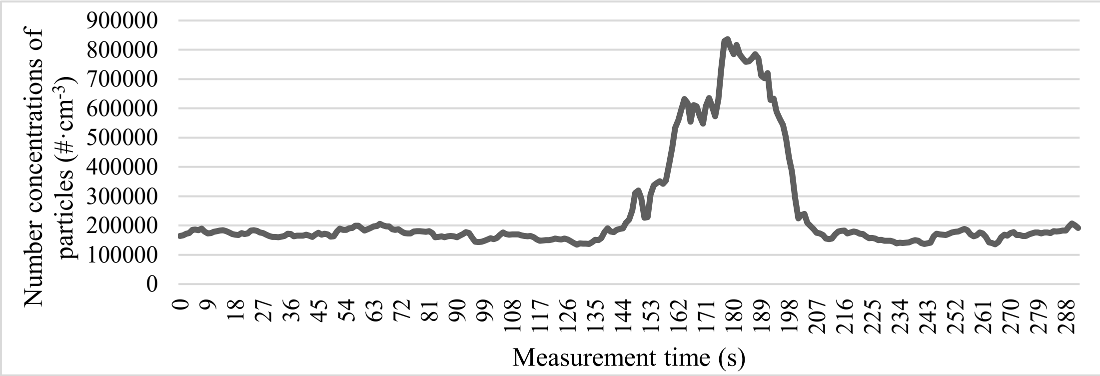

Fig. 3 Number concentrations of particles during the aluminum smelting [own study]

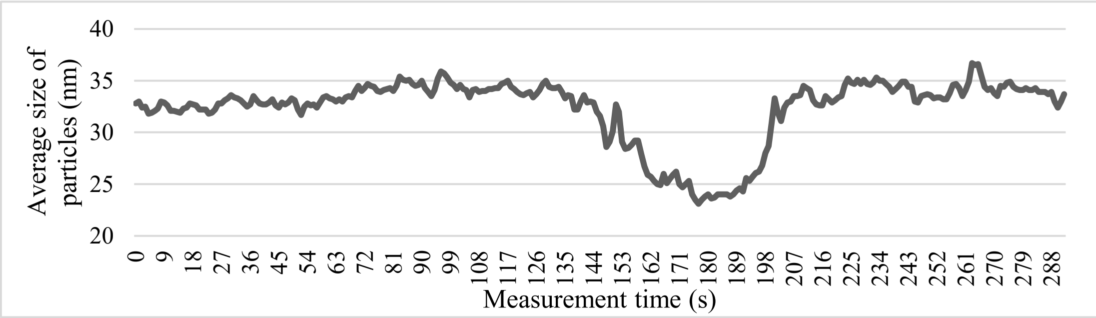

Fig. 4 Average size of particles in aluminum smelting [own study]

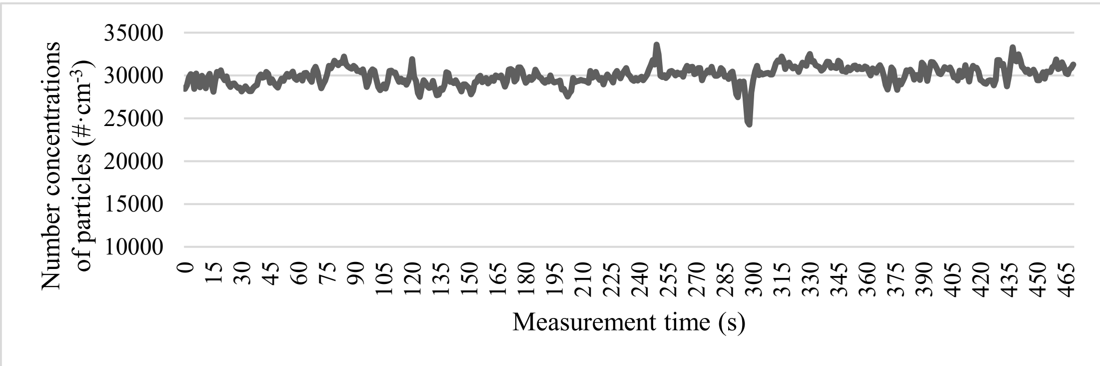

Fig. 5 Number concentrations during our measurements in the 2-line cowshed

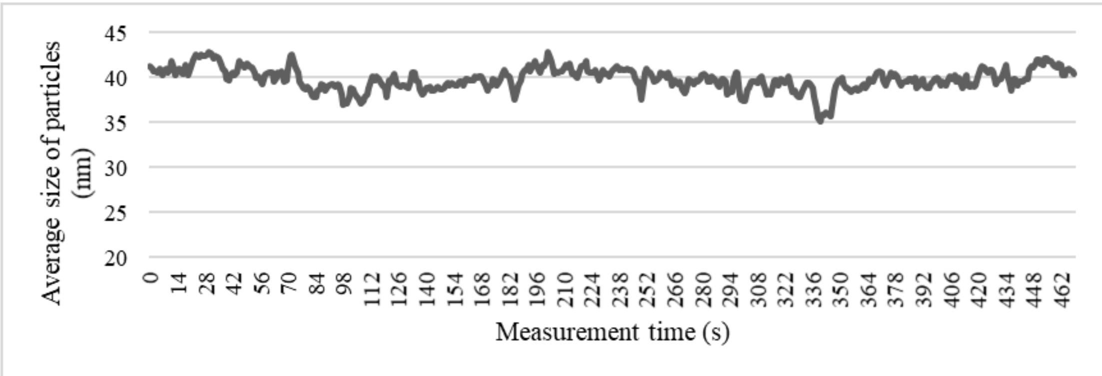

Fig. 6 Average size of particles during the measurements in the 2-line cowshed

3.3 Engineering Production (Illustration of the Detailed Outcomes of the Measurement)

The following figure shows the layout of the engineering plant (welding room and double hall). Measuring points are highlighted in the drawing. Each point is presented in min and max particle concentration in thousand/cm^3 and average nanoparticle value is mentioned in nm.

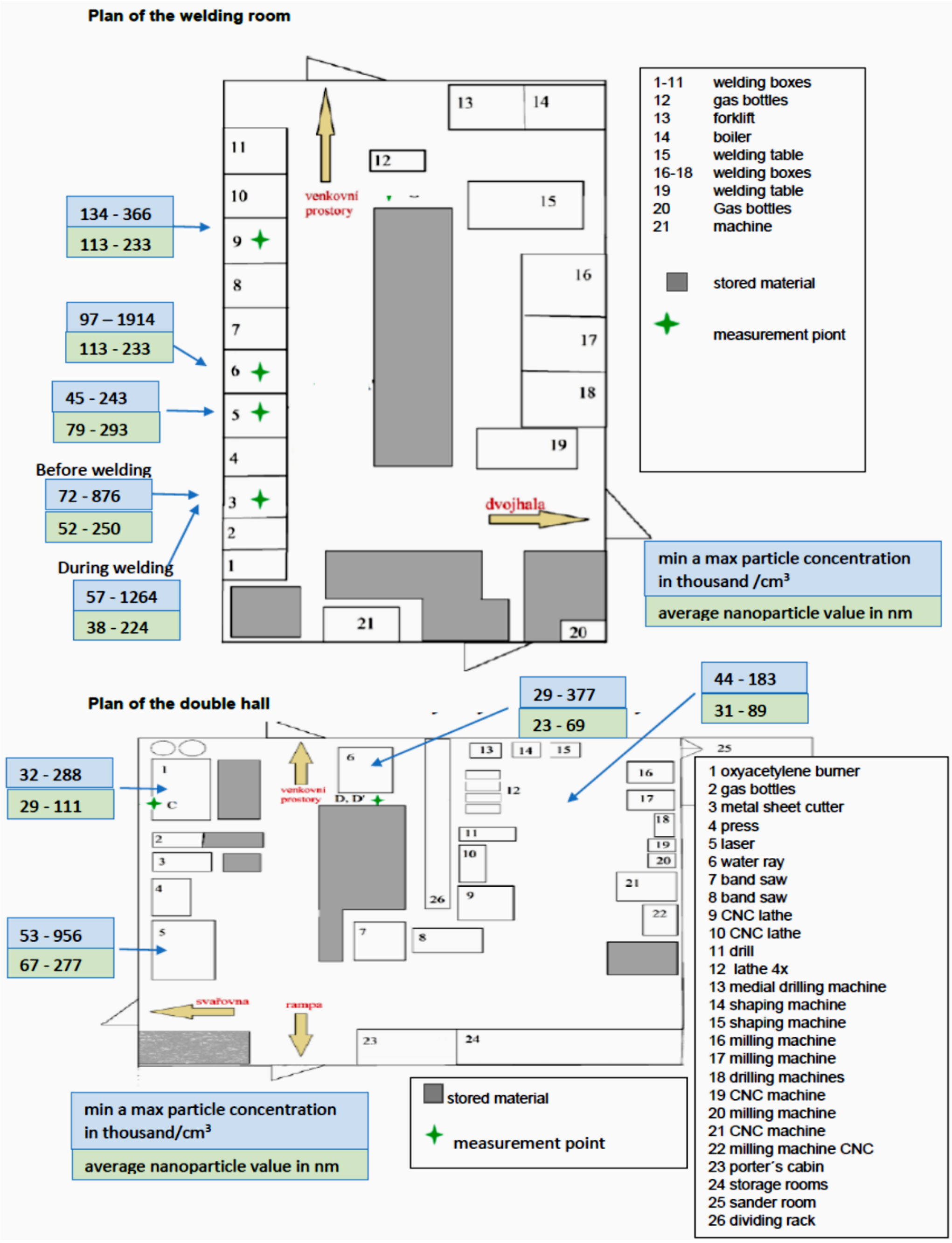

Fig. 7 Illustration figure from the detailed processing of our results of the measurement in the engineering plant (welding room and double hall) [own study]

5. Conclusions

In the group of tested workplaces, the highest risk was found in the smelting and casting of aluminum, and copper soldering and welding in the engineering production. Here, the personal protective devices should be tested for the particular workers and the design of emerging nanoparticles examined with use of the morphological analysis SEM and the chemical microanalysis of the EDAX elements.

A stabile size and low concentration of nanoparticles was found in the cabin of the new combine harvester, in the semi-automatized bakery, and in the 2-line cowshed with the original technological equipment from the 1970's.

Acknowledgements

This article has been supported within the Student Grant Competition 'Development of application and preparation of new carbon nanomaterials and their modification with polymers and other selected materials'. Project number SP2018/137.

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