REVIEW OF CONTROL BANDING APPROACHES FOR OCCUPATIONAL EXPOSURE ASSESSMENT OF NANOMATERIALS

PRICHYSTALOVA Radka[1], KOCURKOVA Lucie[1], BERNATIKOVA Sarka[1], BRZICOVA Tana[1], DVORAKOVA Kristina[1]

[1]*VSB - Technical University of Ostrava, Czech Republic, EU*

Abstract

The employers shall ensure adequate safety and health protection of the workers. They are obliged to carry out risk assessment and take appropriate measures for risk prevention and control related to all relevant workplace hazards. However, sound risk assessment requires reliable comprehensive information on hazard (toxicity) and exposure which may not be available for many, especially novel, substances and materials, such as nanomaterials (both engineered and accidental). The generally accepted approach used for preliminary risk assessment of nanomaterials is Control banding (CB). CB is a pragmatic tool to manage the risk resulting from exposure to potentially hazardous substances in the absence of firm toxicological and exposure data. Currently, several CB tools have been developed within the international research activities. The aim of this study was to review the CB tools that are presently available for qualitative, semi-quantitative or quantitative estimation of exposure and risk associated with the manufacture and professional use of nanomaterials. The applicability of the various tools was evaluated using two real-life occupational exposure scenarios. Furthermore, the positives, negatives (limitations) of these tools, and the recommendation on their usefulness in particular industrial sectors were analysed.

Keywords: Nanomaterials, occupational exposure, risk assessment, control banding tools

1. INTRODUCTION

The employers shall ensure adequate safety and health protection of the workers. They are obliged to carry out the risk assessment and take appropriate measures for risk prevention and control related to all relevant workplace hazards. However, sound risk assessment requires reliable comprehensive information on hazard (toxicity) and exposure which may not be available for many, especially novel, substances and materials, such as nanomaterials (both engineered and accidental). Engineered nanomaterials (ENMs) are used today in a wide range of nanoproducts and applications [1].

The immense beneficial potential of ENMs may be threatened by limited understanding of related occupational health and safety aspects. Despite the extensive research in the field of nanotoxicology and exposure to ENM, knowledge for comprehensive risk assessment and management of ENM is still missing. Some preliminary tools were introduced to help at least to predict the potential health risks related to ENM. Among them, control banding tools (CB tools), that are already in use for conventional chemicals, were adjusted for ENM. CB tools are considered pragmatic tools to manage the risk resulting from exposure to a wide variety of potentially hazardous substances in the absence of firm toxicological and exposure information, that is based on combining hazard and exposure into control or risk bands [2]. CB tools for ENM can be used as a first approach to controlling workplace exposure to ENM. The identification of critical processes is achieved by ranking associated risks based mainly on the potential of a substance to cause adverse health effects and the probability of being exposed to it. The determination of the level of exposure is therefore extremely important to prioritize occupational activities according to potential risk. Since precise exposure modeling is extremely complex, most available CB tools rely on simplified approaches which allow describing an exposure situation or exposure scenario by choosing a limited set of exposure determinants (e.g. production volume, process category, room volume, level of dustiness, etc). These determinants are then combined with an exposure model, which may embed more or less physics, to give a final score allowing assignment of exposure level (band) and subsequently the risk level (band). Based on the risk band, some of the CB tools suggest the level of basic risk management measures to be applied. Currently, several CB tools have been developed within the international research activities. The aim of this study was to review the CB tools that are presently available for qualitative, semi-quantitative or quantitative estimation of exposure and risk associated with the manufacture and professional use of nanomaterials. The applicability of the various tools was evaluated using two real-life occupational exposure scenarios. Furthermore, the positives, negatives (limitations) of these tools and the recommendation on their usefulness in particular industrial sectors were analysed.

2. METHODOLOGY

The list of actual CB tools was carried out with the focus on the innovated or new tools for modelling of exposure to ENM. The research was done using the following key words and their combinations: “control banding”, “tool”, “nanomaterial”, “modeling of exposure”, “risk assessment”, “risk management”. The used sources were Web of Science, PubMed, and Google. The research was carried out for the period 2000 until 11.3.2017. The selection of tools was based on the criterion: applicability for occupational exposure. The selected tools were reviewed with the focus on the characteristics of the inputs, their risk management approach, presentation of the results (quantitative or qualitative), and description of their limitations. The applicability of the various tools was evaluated using two real-life occupational exposure scenarios. Based on these case studies was also developed a flowchart as the tool for selection of appropriate CB tool.

The real-life occupational exposure scenarios were obtained from field studies which were conducted in technology that produces composite materials, stiffeners, polyurethane foams, etc. After familiarizing with traffic and substances, the following work operations (WO) were selected to measure occupational exposure.

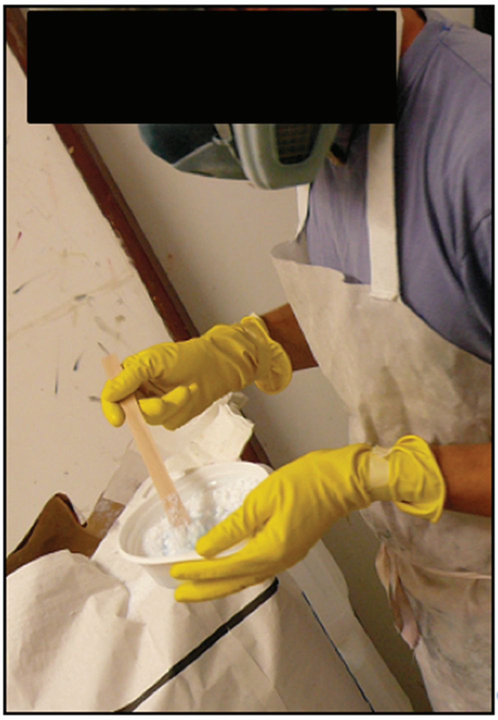

Figure 1 Mixing manually mixtures for shipbuilding

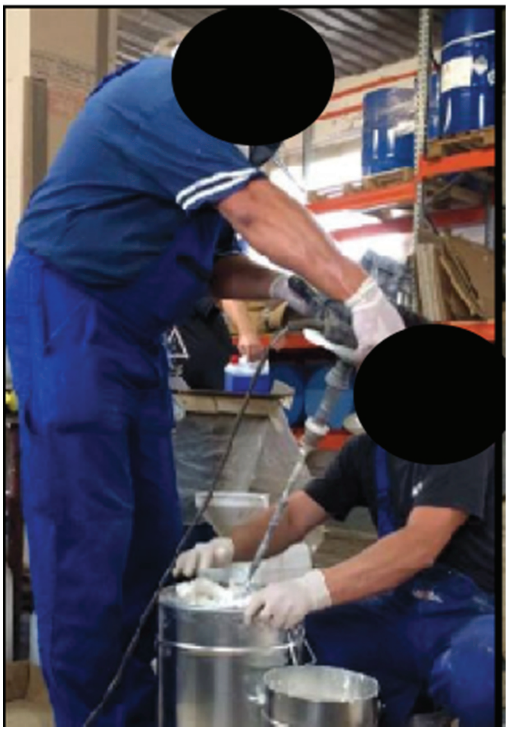

Figure 2 Mixing the mixture with a stirrer

The real-life occupational exposure scenarios were (WO 1) - Mixing manually mixtures for shipbuilding, and (WO 2) - Mixing the mixture with an electric stirrer.

WO1 At the hand-made storage (preparation material), Aerosil 200, Epoxy resin and Dough were hardened. The mixture was carefully mixed in a small dish to form a solid paste weighing approx. 200 g. These activities are shown in **Figure 1**.

WO 2 The mixture of Expancel and Epoxy resin was weighed into the barrel in a large warehouse. The stirrer was carefully mixed with the hand stirrer over the closed lid. The mixture gets volume and sometimes it is necessary to open the barrel and remove the mass. The resulting product was left in barrels to not lose its properties. See **Figure 2**.

The materials used in the working operations are Aerosil 200 (Hydrophilic Fumed Silica) and Expancel 461 DET 40 d25. The form of both material is white solid fine powder. The specifications of both materials are described in **Table 1**.

Table 1 Specification of materials used in the real-life occupational exposure scenarios

Properties	**Aerosil 200**	**Expancel**
Typical particle diameter	12 nm	35 nm - 55 μm
Specific surface	200 $m^2/g \pm 25$	-
Physical form	Solid/fine powder	Solid/fine powder
Color	White	White

3. RESULTS

It was identified in total 9 CB tools which are applicable for assessment of risk from exposure to nanomaterials. The tools are described in the following **Table 2**. It is described in **Table 2** also the approach for risk management of the tool, the area where it can be used, and the limitations of the tools.

Table 2 Specification of materials used in the real-life occupational exposure scenarios assessment

CB tool	Risk management approach	Area of use	Limitations
CB Nanotool v 2.0	Separating into the control bands: hazard band (evaluation of hazard) and band of exposure (evaluation of probability) for the process. The combination of these bands is resulted adequate control measures. The appropriate risk management recommendation.	Activities in the labs; using of small amount of materials.	The hazard information asked by the tool are very rarely studied. The exposure band contains limitation number of exposure determinants.
Stoffenmanager nano	Concrete description of: nanomaterial and its properties; process how material is used; description of workplace and conditions. Assessment of risks and the following plan with risk management measures.	The nanomaterials of size up to 100 nm and specific surface area (nanoparticles, agglomerates and aggregates).	If the nanomaterial belongs into the group of the highest hazard, the risk is assessed as high without any attention to the level of exposure (e.g. fibres)..

(continue)			
CB tool	**Risk management approach**	**Area of use**	**Limitations**
Nanosafer	Description of properties of: nanomaterial, its bulk form, the occupational exposure limit, toxicological information etc. Description of process - conditions of nanomaterial use. The qualitative evaluation of exposure and recommendation of RMMs.	The workplace handling with powder nanomaterial and accidental nanomaterials.	The hazard is mainly assessed based on the physical parameters. Just for particles.
ANSES method	Qualitative risk assessment method. The analysis of available hazard information about the nanomaterial; estimation of emission potential of material; set up the action plan for decreasing the possible risks, and its realization.	All work places.	The limitation in the available information about the hazard of nanomaterial.

The better orientation in the selection of the appropriate tool (or set of tools), the flowchart was developed for supporting the decision making, see **Figure 3**. This flowchart was used for selection of the tool (tools) for the assessment of real-life occupational exposure scenarios.

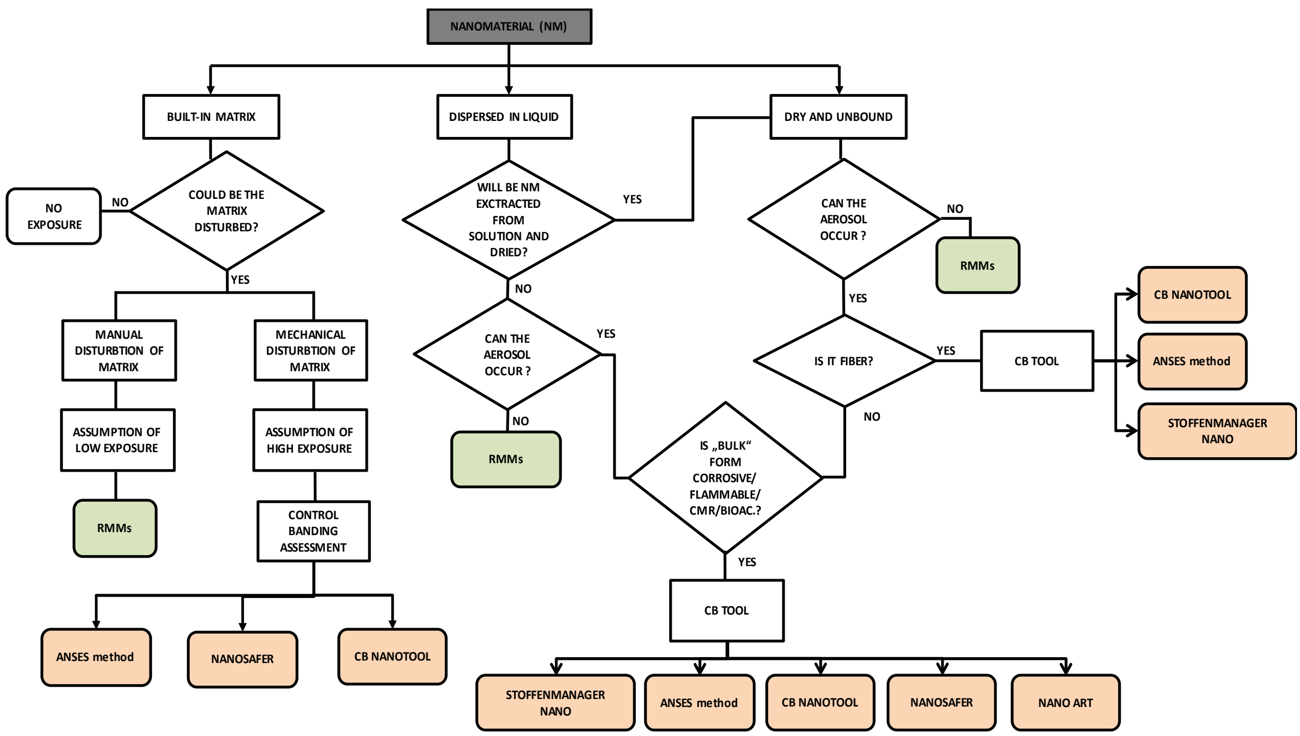

Figure 3 The flowchart for selection of CB tool (tools)

The selected tools were CB nanotool, Stoffenmanager nano and ANSES method. The results obtained from these tools for two work exposure scenario are presented in the following risk matrix table, **Table 3**.

Table 3 Results of risk assessment from CB nanotool, Stoffenmanager and ANSES method presented in risk matrix

Hazard		Probability			
		Extremely unlikely (0-25)	Less unlikely (26-50)	Likely (51-75)	Expected (76-100)
	Very high (76-100)				**WO 2**(Stoffenmanager)) **WO 2**(ANSES method)
	High (51-75)		**WO 1** (CB nanotool) **WO 1** (ANSES method)	**WO 2**(CB nanotool) **WO 1**(Stoffenmanager)	
	Medium (26-50)				
	Low (0-25)				

The illustration of results in the matrix table is showing the differences between estimated (qualitatively) risks. Based on it, the CB nanotool underestimates the risk in the WO2. The WO1 was assessed by Stoffenmanager as “higher” risk compares to the other tools. The reason is that Stoffenmanager is strongly influenced by the hazard properties of the nanomaterial without taking into account the level (or possibility) of exposure.

4. CONCLUSION

Based on the review were identified CB tools possible to use for risk management of occupational exposure to nanomaterials. The flowchart for the specific selection of the tool was created. The tools selected by the flowchart undergone the case study of assessment of two different work exposure scenarios.

ACKNOWLEDGEMENTS

This work was prepared within the project „ The usefulness of control banding tools for insurance of nanotechnology health risk management“ SP2017/93 with the financial support from the Ministry of Education, Youth and Sports, Czech Republic.

REFERENCES

[1] BOLDRIN, A., HANSEN, S.F., BAUN, A., HARTMANN, N. I. B., ASTRUP, T. F. Environmental exposure assessment framework for nanoparticles in solid waste. Journal of Nanoparticle Research, 2014, vol. 16, pp. 1-19.

[2] BROUWER, D. Control Banding Approaches for Nanomaterials. Ann. Occup. Hyg., Vol. 56, No. 5, pp. 506-514, 2012.

[3] GRIDELET, L., BELBECQ, P., HERVÉ, L., BOISSOLLE, P., FLUERY, D., KOWAL, S., FAYET, G. (2015). Proposal of a new risk assessment method for the handling of powders and nanomaterials. *Industrial Health*, vol. 53, pp. 56-58.

[4] CB nanotool: Control Banding for Nanotechnology Applications. Available on: http://controlbanding.net/Services.html

[5] NANOSAFER: Control-Banding and Risk Management tool. Available on: http://www.nanosafer.org/

[6] ART: Advanced Reach Tool 1.5. Available on: https://www.advancedreachtool.com/

[7] STOFFENMANAGER NANO. Available on:: https://nano.stoffenmanager.nl/