Article

NANOMATERIAL RISK ASSESSMENT TOOLS 02

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REVIEW | The International Organisation for Standardisation (ISO) defines the term 'nanomaterial' as 'material with any external dimensions in the nanoscale or having an internal structure or surface structure in the nanoscale.' The term 'nanoscale' is defined as size range from approximately 1 nm to 100 nm. Nanomaterials that are naturally occurring (e.g., volcanic ash, soot from forest fires) or are generated as incidental (unintentional) by-products of combustion processes (e.g., welding, diesel engines) are usually physically and chemically heterogeneous and often termed 'ultrafine particles. Engineered nanomaterials, on the other hand, are intentionally produced and designed with physicochemical properties for a specific purpose or function. Database from STATNANO indicates the application of nanomaterials around the world involving 2400 companies from 61 countries. Electronic, medicine and construction are major industries of using the nanomaterials in the product (Statnano, 2020).

Nanomaterials are the complex chemicals substances or materials that are manufactured and used at a very small scale. Therefore, health issues posed by nanomaterials becoming concern nowadays. Table 1 showed the previous cases related to nanomaterials health issues.

Table 1

Author	**Activity/Process**	**Syndrome**	**Evidence**
Phillips, J. I., Green, F. Y., Davies, J. C., & Murray, J. (2010). Pulmonary and systemic toxicity following exposure to nickel nanoparticles. American journal of industrial medicine, 53(8), 763-767.	Spraying nickel onto bushes for turbine bearings using a metal arc process	Adult respiratory distress syndrome (ARDS)	Nickel particles <25 nm in diameter were identified in lung macrophages using transmission electron microscopy
Song, Y., Li, X., & Du, X. (2009). Exposure to nanoparticles is related to pleural effusion, pulmonary fibrosis, and granuloma. European respiratory journal, 34(3), 559-567.	Polyester spray painting	Shortness of breath, and the same clinical findings of pleural effusion and pericardial effusion	Nanoparticles were observed to lodge in the cytoplasm and caryoplasm of pulmonary epithelial, mesothelial cells and chest fluid
Cheng, T. H., Ko, F. C., Chang, J. L., & Wu, K. A. (2012). Bronchiolitis obliterans organizing pneumonia due to titanium nanoparticles in the paint. The Annals of thoracic surgery, 93(2), 666-669.	Polyester powder paint	Bronchiolitis obliterans organizing pneumonia	Titanium dioxide nanoparticles were present in the pulmonary sample.

Because of the absence of Occupational Exposure Limit (OEL) specified for nanomaterials, few organizations or researchers put the effort on the development of risk assessment tools for nanomaterials exposure.

To the date, there are several tools were developed to assess the exposure of nanomaterials. These tools mainly to help developers, producers, and users of nanomaterials to complete first precautionary risk estimations and apply precautionary exposure control. This article will describe three risk assessment tools available for nanomaterials.

CB Nano Tool (https://controlbanding.llnl.gov)

CB Nano Tool was developed by Lawrence Livermore National Laboratory (LLNL) in the United States. CB Nano Tool using the control banding (CB) approach which offers simplified processes for controlling worker exposures in the absence of firm toxicological and exposure information. Two type information needed to complete the assessment using this tool which is the severity factor and probability factor.

Severity factors included the following characteristics; surface chemistry, particle shape, particle diameter, solubility, carcinogenicity, reproductive toxicity, mutagenicity, dermal toxicity, the toxicity of parent material, carcinogenicity of parent material, reproductive toxicity of parent material, mutagenicity of parent material, and dermal hazard potential of parent material. The overall severity score is determined based on the sum of all the points from the severity factors. The maximum rating is 100. On the other hand, the probability factors are factors that determining the extent to which employees may be potentially exposed to nanoscale materials. The probability factors included; estimated amount of nanomaterial used during task, dustiness/mistiness, number of employees with similar exposure, frequency of activity, and duration of activity. The maximum score for probability is 100. Based on the severity score and probability score for an activity, the overall level of risk and corresponding control band is determined by the matrix shown in figure 1

Severity score	Probability Score	Extremely Unlikely (0-25)	Less Likely (26-50)	Likely (51-75)	Probable (76-100)
	Very High (76-100)	RL 3	RL 3	RL 4	RL 4
	High (51-75)	RL 2	RL 2	RL 3	RL 4
	Medium (26-50)	RL 1	RL 1	RL 2	RL 3
	Low (0-25)	RL 1	RL 1	RL 1	RL 2

Figure 1 Risk matrix of CB Nano Tool

Risk level (RL) matrix as a function of severity and probability scores. Control bands by risk level: RL 1, General Ventilation; RL 2, Fume hoods or local exhaust ventilation; RL 3, Containment; RL 4, Seek specialist advice. Brouwer, D. H. (2012) conclude that CB Nano Tool specifically focuses on a preliminary qualitative risk assessment for research activities and facilities with relative small-scale use of a wide variety of manufactured nanomaterials.

In a study by Golbabai et al. (2015) using CB Nano Tool in assessing nanomaterial at research, the laboratory found the tool are simple qualitative risk assessment methods, applicable, and comprehensive way for risk assessment.

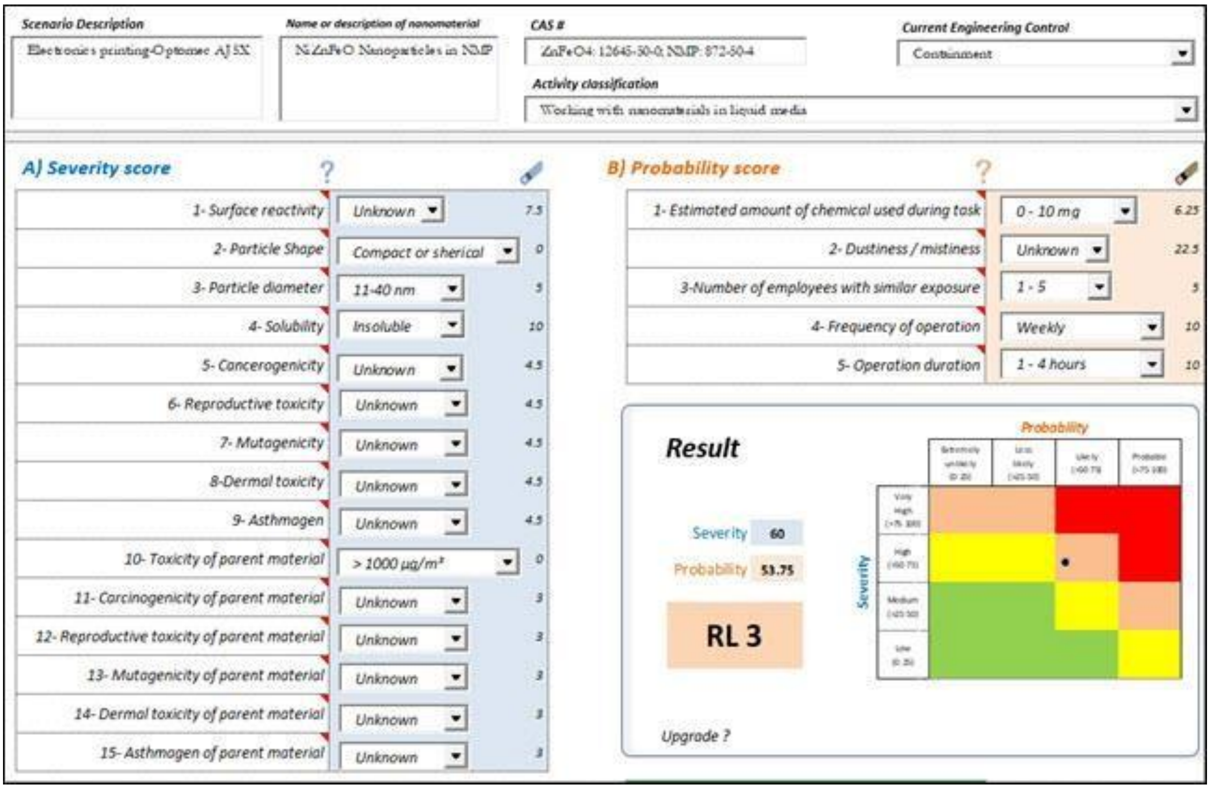

Figure 2 CB Nano Tool interface

NanoSafer (http://www.nanosafer.org)

NanoSafer was developed by the National Research Centre for the Working Environment, Copenhagen, Denmark. The current version of this tool is 1.1 beta. NanoSafer is a combined control-banding and risk management tool that enables assessment of the risk level and recommended exposure control associated with production and use of manufactured nanomaterials (e.g., nanoparticles, nanoflakes, nanofibers, and nanotubes) in specific work scenarios. In addition to manufactured nanomaterials, the tool can also be used to assess and manage emissions from nanoparticle-forming processes.

The exposure assessment is estimated using the workroom dimensions, ventilation rate, powder use rate, duration. To use this tool, the set of information is needed to the acquired best estimate of nanomaterials exposure. Supplier's technical data sheet, safety data sheet delivered with the material (nearest analog bulk material or a nano specific version) occupational exposure limit for respirable dust (nearest analog bulk material or a nano specific version) data on the work situation data on the workplace are the kind of information needed while using the NanoSafer.

Nanosafer distinguishes five risk levels, based on the combination of the five exposure bands and four hazard bands. The four hazard bands are related to the toxicological profile (of the bulk material) or reflect a precautionary approach. The risk levels are linked to control measures. The exposure bands are leading for risk classification because the highest risk level is assigned for the highest exposure band, despite the level of the hazard band. However, because the exposure band is based on the ratio of the OEL and the actual exposure, it makes sense to allocate the highest risk band in case of ratios >1.

Brouwer, D. H. (2012) concludes the Nanosafer focuses on specific occupational powder-handling scenarios and provides a close-to 'semi-quantitative' risk evaluation. This spectrum also indicates the range of different target groups of users and applicability domains.

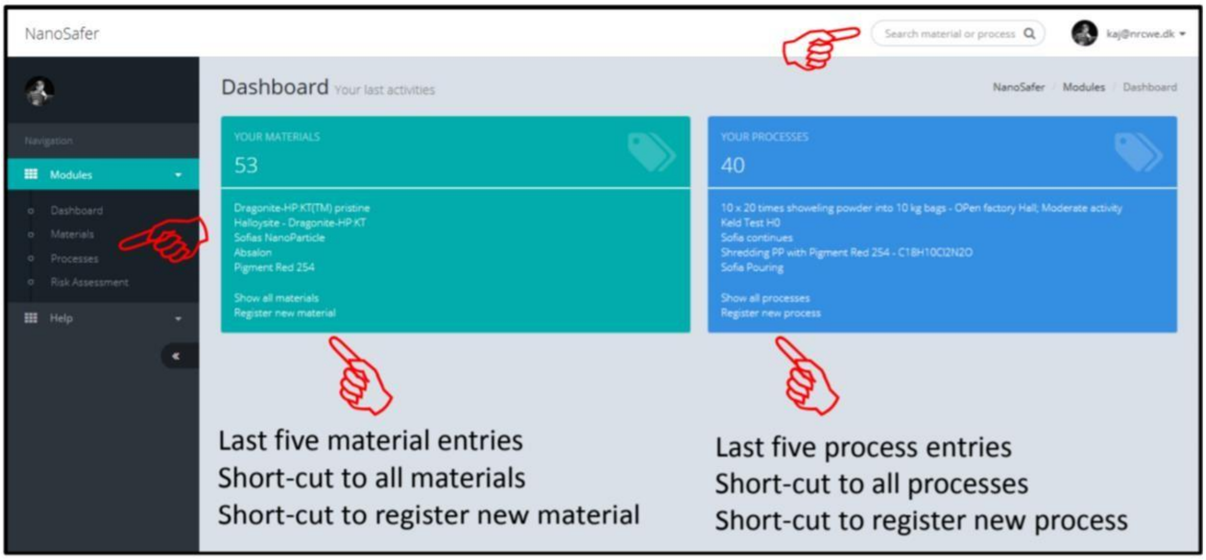

Figure 3 Interface Nanosafer

Stoffenmanager-Nano (https://nano.stoffenmanager.com)

Stoffenmanager-Nano is the additional module offer by Stoffenmanager, an online risk assessment free web application in June 2011. Stoffenmanager was developed by TNO, Arbo Unie and BECO (EY), and was commissioned by the Dutch Ministry of Social Affairs and Employment. Like the other nanomaterials risk assessment tools, this instrument also adapts the risk banding approach.

There some criteria need to meet first before using this tools which are particles are not (water) soluble, the particles are purposely (synthetically) produced and not released as unintentional by-products, such as the particle production as a result of incomplete combustion processes, the size of the primary particle is smaller than 100 nm and/or the specific surface area of a nanopowder is larger than 60 m^2/g, and it concerns single particles as well as agglomerates or aggregates. Figure 2 illustrates the step of Stoffenmanager Nano hazard banding approach.

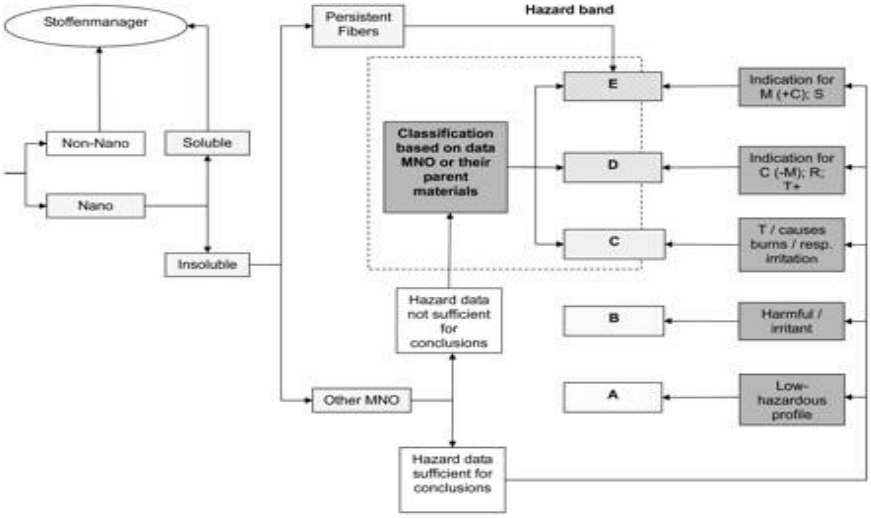

Figure 4 Schematic illustration of the stepwise approach for hazard banding

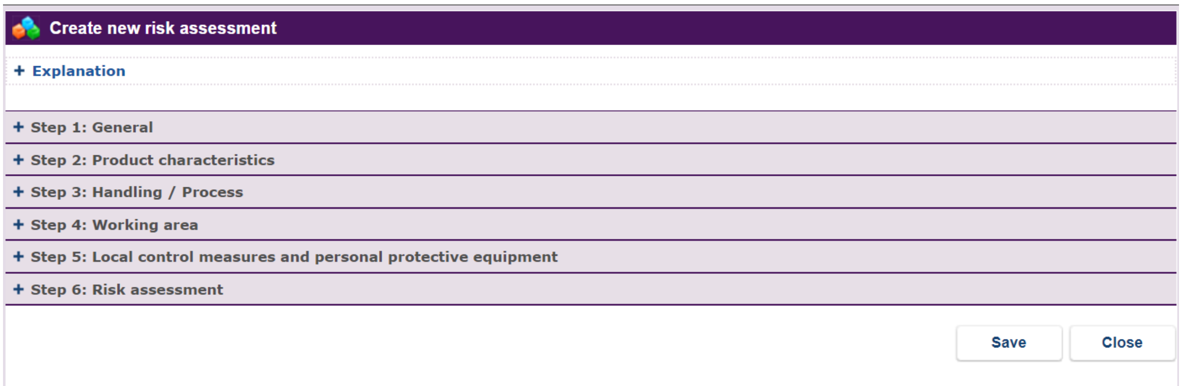

Figure 5 Interface of Stoffenmanager Nano

Brouwer, D. H. (2012), in a comparison of six (6) control banding tools for nanomaterials risk assessment, has concluded Stoffenmanager Nano and Nanosafer enable a more detailed assessment of exposure. Similar findings by Wang et al. (2020) in the comparison of six (6) nanomaterial risk tools also was found that Stoffenmanager Nano and Nanosafer are more suitable for the risk assessment of this workshop comparing to the other four tools.

The ongoing research funded by NIOSH and lead by UTP "Prediction of Nanomaterials Risk Using Bayesian Network" aim similar to the output like the existing tools. This research objective was to help the user of nanomaterials to predict the health risk of nanomaterials using Bayesian Network and to determine the control strategies to minimize the risk of nanomaterials (Safety, 2020).

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