Article

NANOMATERIALS RISK ASSESSMENT TOOLS 01

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REVIEW | Nowadays, nanotechnology is growing rapidly, and nanomaterials-based products are increasingly being offered in many industries such as automotive, agriculture, construction, cosmetics, electronics, and more (www.statnano.com). The International Organization for Standardization (ISO/TS 80004-1:2015) defines the term 'nanomaterial' as a 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 nanometer (nm) to 100 nm. The sizes of nanomaterials compared to biological components are shown in Figure 1.

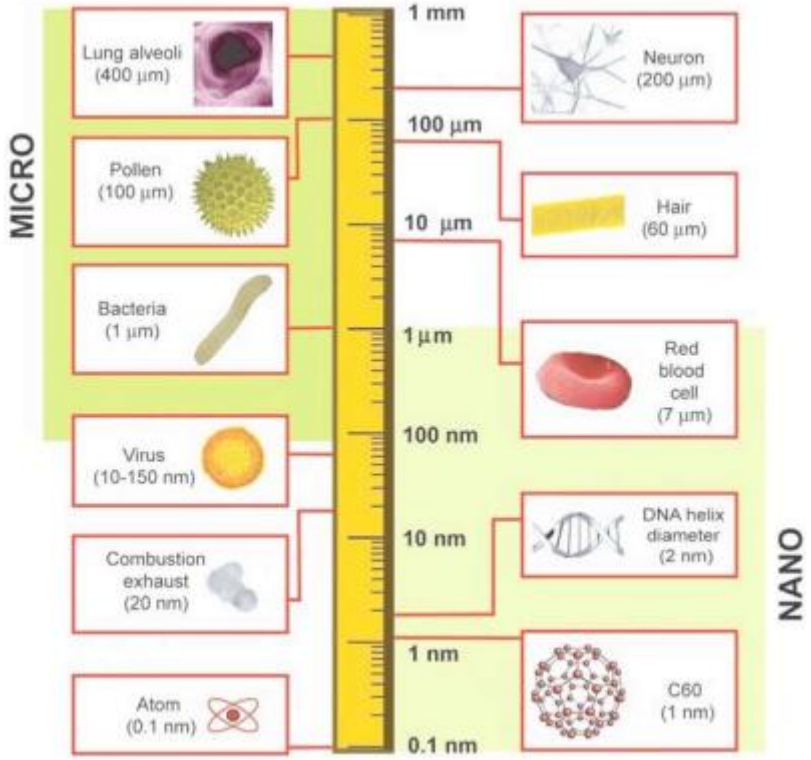

Figure 1. Sizes of nanomaterials compared to biological component (Nanomaterials and Nanoparticles: Sources and Toxicity, 2007)

Due to its unique chemical and physical properties compared to its macro counterpart, health issues which might be posed by nanomaterials has become a great concern among occupational safety and health (OSH) researchers and practitioners nowadays. To date, there are limited occupational exposure limits (OEL) that exist specifically for nanomaterials such as respirable carbon nanotubes, carbon nanofibers, and titanium dioxide based on National Institute for Occupational Safety and Health (NIOSH) proposed Recommended Exposure Limit (REL). However, exposure limits for other nanomaterials are not yet present, and there is a need for employers to minimize the exposure of nanomaterials to those who handle them.

Therefore, an effort on the development of risk assessment tools for nanomaterials exposure has been carried out by certain organizations and researchers to assess the exposure

of nanomaterials. These tools are mainly to help developers, producers, and users of nanomaterials to complete first precautionary risk estimations and apply precautionary exposure control.

Most of the existing risk assessment tools for nanomaterials are using control banding (CB) method. Control banding is an assessment method that can be used to manage workplace risks. It is a process that matches, for example, a control measure to a range or "band" of hazards. The overall goal of control banding is to help workplaces by providing an "easy to understand" and "easy to apply" approach to controlling hazards. Control banding is also often used to determine control measures when occupational exposure limits are not known.

Existing risk assessment tools for nanomaterials are shown in Figure 2. This article provides an introduction by view of four (4) out of seven (7) available tools.

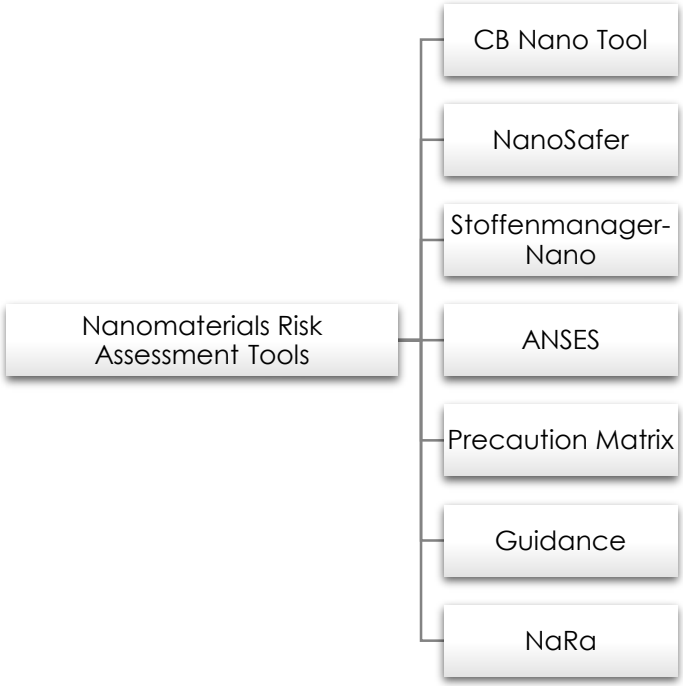

Figure 2. Risk assessment tools for nanomaterials

CB Nano Tool (controlbanding.llnl.gov) was developed by Lawrence Livermore National Laboratory (LLNL) in the United States (US) for use at US research laboratory. Using a control banding (CB) approach, CB Nano Tool aims to deliver simplified processes for controlling worker exposures due to limited toxicological and exposure information.

Two (2) types of information are needed by using this tool, which is severity factors and probability factors, as showed in Figure 3. Based on the severity score and probability score for an activity, the overall level of risk and corresponding control band. There are four (4) control bands offered through the CB Nano Tool, depending on the level of risk. RL 1, General ventilation; RL 2, Fume hoods or local exhaust ventilation; RL 3, Containment; RL 4, Seek specialist advice.

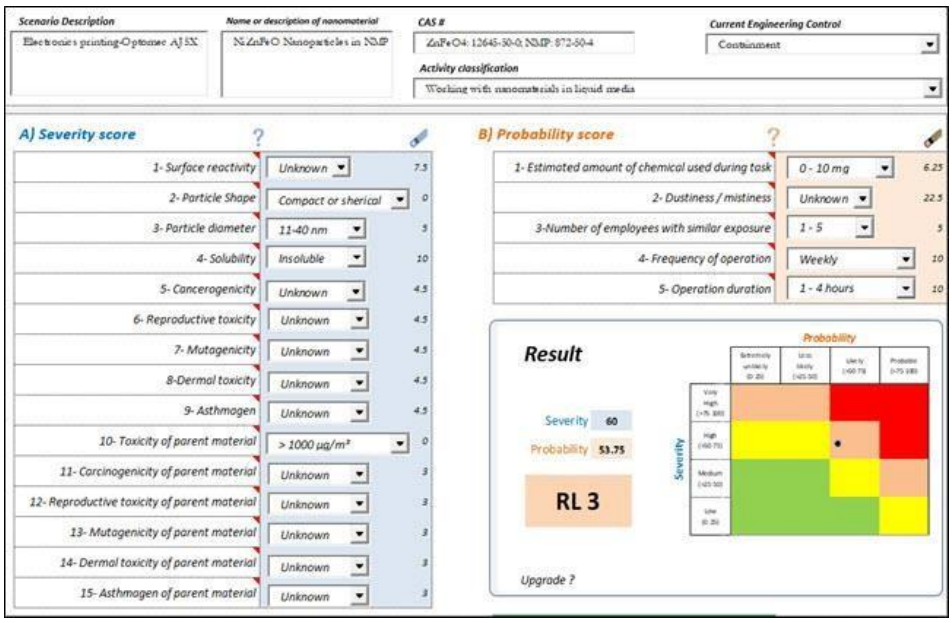

Figure 3. The interface of CB Nano Tool

Website of CB Nano Tool: https://controlbanding.llnl.gov

NanoSafer is another tool for assessing and control the exposures of nanomaterials used in the workplace. This web-based tool was developed by the National Research Centre for the Working Environment, Copenhagen, Denmark, and targeting for small and medium businesses (SME). The current version is 1.1 beta.

The hazard evaluation in NanoSafer needs the user to provide some physicochemical inputs, risk sentences of the closest bulk analog compound deemed relevant for the respiratory tract, and the OEL of the closest bulk analog compound. The exposure evaluation is estimated by using the workroom dimensions, ventilation rate, powder use rate, duration.

Control banding and risk management in NanoSafer consist of five (5) risk levels (RL) ranging from low risk to high-risk potential, based on the combination of the five (5) exposure bands and four (4) hazard bands. Each RL will be provided with brief guidance on risk management. Figure 4 showed the interface of web-based NanoSafer

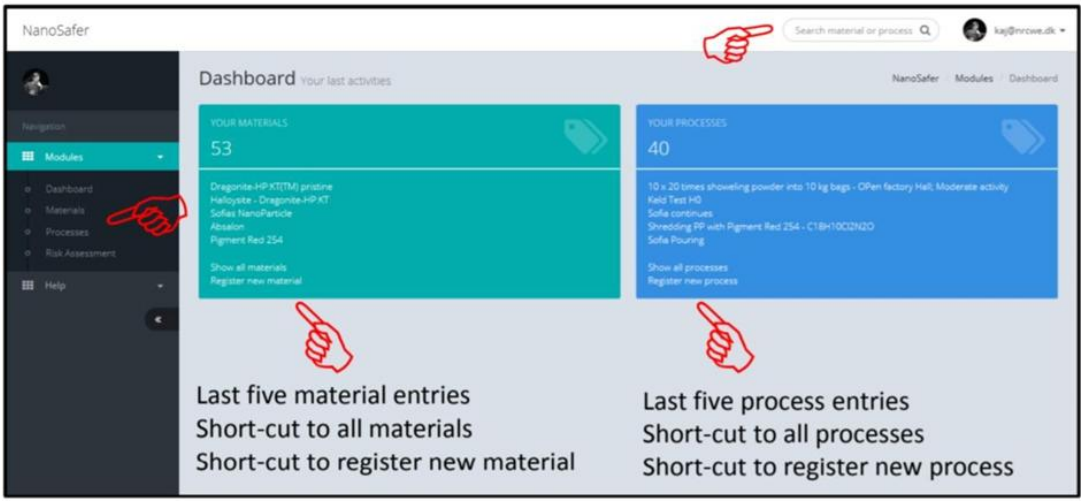

Figure 4. *The interface of web-based NanoSafer*

Website of NanoSafer: **http://nanosafer.org**

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. Not all the types of nanomaterials able to use Stoffenmanager-Nano in assessing the risks. If the nanomaterials are water-soluble, unintentional by-product, a size larger than 100nm, not agglomerates or aggregates single particles, then this tool is not suitable. Stoffenmanger Nano combines the five (5) hazard bands and the four (4) exposure bands into three (3) risk prioritization bands. The highest hazard band is associated with the highest risk priority, independent of the exposure band. Figure 5 showed the schematic illustration of the stepwise approach for hazard banding in Stoffenmanager-Nano.

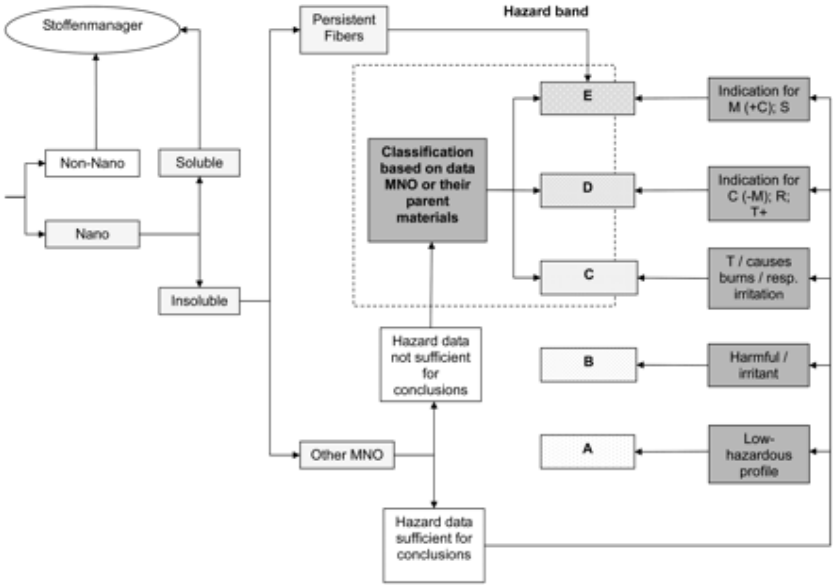

Figure 5. *Schematic illustration of the stepwise approach for hazard banding in Stoffenmanager-Nano*

Website of Stoffenmanager-Nano: **https://nano.stoffenmanager.com**

Nanomaterial Risk Assessment (NaRa) is the method outlined in Guideline on Control and Safe Handling of Nanomaterial, published by the Department of Occupational Safety and Health (DOSH), Malaysia, in 2018. The guideline's objective is to provide guidance and recommendation on safe handling and control of nanomaterials at the workplace.

Like other nanomaterials risk assessment tools, NaRa also uses a band control approach adapted from COSHH Essential and GoodNanoGuide. The risk level of the nanomaterials depending on the state of nanomaterials (bound, potential, unbound/free), duration of exposure (short, medium, long), and three (3) hazard groups as shown in Figure 6. Like the CB Nano Tool, there are four (4) control bands with guide control measures of (Band 1) general ventilation or personal protection equipment (PPE), (Band 2) engineering control, (Band 3) containment, and (Band 4) seek specialist advice.

Degree of Release / Exposure Duration	Bound Materials	Potential Release	Free / Unbound
Hazard Group A (Known to be inert)			
Short	1	1	2
Medium	1	1	2
Long	1	2	2
Hazard Group B (Understand reactivity/function)			
Short	1	2	2
Medium	1	2	3
Long	1	3	3
Hazard Group C (Unknown properties)			
Short	2	2	3
Medium	2	3	4
Long	2	4	4

Figure 6. *Control matrix of NaRa*

Website of DOSH: **https://www.dosh.gov.my/index.php**

NIOSH Malaysia has funded the on-going research lead by **University Technology Petronas (UTP)** aim for developing a similar tool. This research objective is to help the user of nanomaterials to predict the health risk from limited data and to minimize the risk of nanomaterials by improving the control banding strategies outlined in existing guidelines.

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