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Risk assessment in a research laboratory during sol–gel synthesis of nano-TiO_2

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A B S T R A C T

The occupational risks in the nanotechnology research laboratories are an important topic since a great number of researchers are involved in this area. The risk assessment performed by both qualitative and quantitative methods is a necessary step for the management of the occupational risks. Risk assessment could be performed by qualitative methods that gather consensus in the scientific community. It is also possible to use quantitative methods, based in different technics and metrics, as indicative exposure limits are been settled by several institutions. While performing the risk assessment, the information on the materials used is very important and, if it is not updated, it could create a bias in the assessment results. The exposure to TiO_2 nanoparticles risk was assessed in a research laboratory using a quantitative exposure method and qualitative risk assessment methods. It was found the results from direct-reading Condensation Particle Counter (CPC) equipment and the CB Nanotool seem to be related and aligned, while the results obtained from the use of the Stoffenmanager Nano seem to indicate a higher risk level.

1. Introduction

There is a huge amount effort put into the research of new materials in the field of nanotechnology. Most industrialized countries promote the research programmes of their universities, research institutions and companies (OECD, 2009). Portugal is not an exception, and Portuguese universities have several research teams working in the area of nanotechnology. Since 2004, the number of papers on nanotechnology published by researchers from Portuguese universities has increased (Eugénio and Fatal, 2010), reflecting the work done in several fields, such as materials, electronics, chemistry and health care, among others.

The occupational safety and hygiene (OSH) issues in nanotechnology research laboratories are receiving special attention due to the increasing activity in the field. As researchers are dealing with materials with unknown or poorly known proprieties, a precautionary approach to the risks is very important (Groso et al., 2010). These concerns are also reflected in the number of publications from several Health & Safety-related institutions, which have established safety guidelines for nanotechnology research laboratories (NIOSH, 2012; The UK NanoSafety Partnership Group, 2012).

Considering that the quantitative methods often used in Occupational Hygiene (OH) are not fully suited to assessing the hazards of nanoparticle exposure, qualitative risk assessment tools have garnered interest among researchers and practitioners in the field of occupational safety and hygiene (Silva et al., 2013). Several methods based on different approaches, aims and with different levels of complexity have been developed in recent years. Vervoort (2012), for an example, identified 32 different methods in a literature review carried out in 2012 (Vervoort, 2012). Qualitative risk assessment tools for nanoparticles based on the control banding (CB) approach have been discussed as useful tools for risk assessment related to worker's exposure to engineered nanoparticles, and several authors and institutions have found it helpful in nanotechnology occupational risk management (Beaudrie and Kandlikar, 2011; Environment Directorate OECD, 2010a; Kuempel et al., 2012; Murashov and Howard, 2009; Ostiguy et al., 2009; Schulte et al., 2010a; Technical Committee ISO/TC 229, 2012a; The UK NanoSafety Partnership Group, 2012). The CB risk assessment approaches have been tested in research environments (Groso and Meyer, 2013; Paik et al., 2008) and their appropriateness has been discussed (Brouwer, 2012).

Quantitative methods to measure the concentration of airborne nanoparticles were also able to be used to assess the exposure in research laboratories (Fleury et al., 2013; Ramachandran et al.,

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2011), resulting in the advancement of OSH intervention in the field of nanotechnology.

The present study was conducted in the materials research laboratory of a Portuguese university, where several nanomaterials and nanostructured materials are studied. During the research process, various situations involving the possible emission of nanoparticles may occur due to the manipulation of nanomaterials. The purpose of this paper is to compare the risk assessment results obtained with different qualitative control banding tools, namely the CB Nanotool and the Stoffenmanager Nano, and the results from measurements of airborne particle concentration.

The underlying research questions in this study were the following: (1) does the quality of information on nanomaterials influence the results of risk assessment; (2) are the qualitative risk assessment methods suitable for assessing risk in a materials research work environment; and (3) do different methodologies, both qualitative and quantitative in nature, identify comparable risk levels for the same tasks?

2. Methodology

2.1. Control banding – CB Nanotool

Based on the control banding risk assessment methodology, an international group of researchers developed a pilot method for the qualitative risk assessment of nanoparticles, known as CB Nanotool (Paik et al., 2008). The referred tool was tested and underwent some adjustments in subsequent research (Zalk et al., 2009).

The method consists of determining the severity of the hazard, based on the nanomaterial's characteristics, and determining the probability of exposure, based on the nature of the work (tasks, operations) to be performed.

2.1.1. Severity determination

The severity of the nanomaterial is determined by the factors presented in Table 1.

The severity band results from the sum of the points of all factors according to the following scale: 0–25: low severity; 26–50: medium severity; 51–75: high severity; 76–100: very high severity.

2.1.2. Probability determination

To determine the exposure probability, the factors present in Table 2 are considered.

To obtain the probability band score, the points of all factors are summed and the probability is determined using the following scale: 0–25: extremely unlikely; 26–50: less likely; 51–75: likely; 76–100: probable.

The risk is assigned using a 4 × 4 matrix, resulting from a combination of the severity and probability determinants (Fig. 1).

One of four risk levels (or control bands) is determined (Zalk et al., 2009):

- RL1 – General ventilation.
- RL2 – Fume hoods or local exhaust ventilation.
- RL3 – Containment.
- RL4 – Seek specialist advice.

To perform the risk assessment, one can use the CB Nanotool 2.0 available on the Internet at http://controlbanding.net/Services.html.

2.2. Stoffenmanager Nano

The Stoffenmanager Nano is a web-based qualitative risk assessment tool regarding operations with manufactured

Table 1
CB Nanotool severity band factors.

Material form	Factor	Characteristics Points assigned				
Parent material hazard (Maximum possible points: 30)	OEL (μg/m^3)	<10 10	10–100 5	101–1000 2.5	Unknown 7.5	>1000 0
	Carcinogen?	Yes 4	No 0	Unknown 3		
	Reproductive hazard?	Yes 4	No 0	Unknown 3		
	Mutagen?	Yes 4	No 0	Unknown 3		
	Dermal hazard?	Yes 4	No 0	Unknown 3		
	Asthmagen?	Yes 4	No 0	Unknown 3		
Nanoscale material hazard (Maximum possible points: 70)	Surface reactivity	High 10	Medium 5	Low 0	Unknown 7.5	
	Particle shape	Tubular or fibrous 10	Anisotropic 5	Compact or spherical 0	Unknown 7.5	
	Particle diameter (nm)	1–10 nm 10	11–40 nm 5	>40 nm 0	Unknown 7.5	
	Solubility	Insoluble 10	Soluble 5	Unknown 7.5		
	Carcinogen?	Yes 6	No 0	Unknown 4.5		
	Reproductive hazard?	Yes 6	No 0	Unknown 4.5		
	Mutagen?	Yes 6	No 0	Unknown 4.5		
	Dermal hazard?	Yes 6	No 0	Unknown 4.5		
	Asthmagen?	Yes 6	No 0	Unknown 4.5		