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Nanotechnologies - Guidelines for Life Cycle Assessment - Application of EN ISO 14044:2006 to Manufactured Nanomaterials

Táto norma obsahuje anglickú verziu európskej normy.
This standard includes the English version of the European Standard.

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English Version

Nanotechnologies - Guidelines for Life Cycle Assessment - Application of EN ISO 14044:2006 to Manufactured Nanomaterials

Nanotechnologies - Lignes directrices pour l'analyse du cycle de vie - Application de l'EN ISO 14044:2006 aux nanomatériaux manufacturés

Nanotechnologien - Leitfaden für Life Cycle Assessments (LCA) - Anwendung der EN ISO 14044:2006 auf industriell hergestellte Nanomaterialien

This Technical Specification (CEN/TS) was approved by CEN on 28 September 2018 for provisional application.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (CEN/TS 17276:2018) has been prepared by Technical Committee CEN/TC 352 “Nanotechnologies”, the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

The purpose of this Technical Specification is to assist the use of the following Life Cycle Assessment standards in their application to manufactured nanomaterials:

— EN ISO 14040:2006, *Environmental management — Life cycle assessment — Principles and framework (ISO 14040:2006)*

— EN ISO 14044:2006, *Environmental management — Life cycle assessment — Requirements and guidelines (ISO 14044:2006)*

This document follows a similar structure to that used for ISO/TR 14047:2012 and ISO/TR 14049:2012, which also provide guidance to the application of EN ISO 14044:2006 in terms of explaining more fully the terminology; as follows:

— ISO/TR 14047:2012, *Environmental management — Life cycle assessment — Illustrative examples on how to apply EN ISO 14044 to impact assessment situations*

— ISO/TR 14049:2012, *Environmental management — Life cycle assessment — Illustrative examples on how to apply EN ISO 14044 to goal and scope definition and inventory analysis*

The main text is “normative” and represents best practice in the application of EN ISO 14044:2006 to Manufactured Nanomaterials. However, it is generally not possible to obtain all the required data, in particular the human and eco-toxicity data, so that alternative approaches are necessary. The current approaches possible are described by three “informative” examples (see Introduction) drawn from different areas of nano-materials that are used to illustrate each stage of the application of EN ISO 14044:2006. It is intended that these examples be updated or replaced as more reliable data becomes available.

Annex A (informative) includes additional discussion on measurement uncertainty.

Annex B (informative) records recent life-cycle-analyses that are provided to give further examples and sources of data.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This Technical Specification provides guidelines on the application of Life Cycle Assessments (LCA) to manufactured nanomaterials (MNMs), in the context of EN ISO 14044:2006. It does not cover incidental nanomaterials. This document is not applicable to life-cycle based Risk Assessment (see [1], [2], [3] for such studies).

The structure of this document follows the structure of EN ISO 14044:2006, and is similar to the related technical reports from ISO [4], [5], showing illustrative examples on how to apply the various steps of the LCA framework. Table 1 gives an overview of the linkage between the content of this Technical Specification and the related content in EN ISO 14044:2006.

Table 1 — Cross references between EN ISO 14044:2006 and the content of this Technical Specification

EN ISO 14044:2006	This Technical Specification	
	Nano-specificity	Example(s)
1 Scope	Clause 1	
2 Normative reference	Clause 2	
3 Terms and definitions	Clause 3 - Definition & use of term for manufactured nanomaterials and LCA	
	Clause 4 - Causes of Uncertainty & Variability in LCA of manufactured nanomaterials	
4 Methodological framework for LCA		
4.1 General requirements		
4.2 Goal & scope definition 4.2.1 General 4.2.2 Goal of the study 4.2.3 Scope of the study	Clause 5 - Choice of an appropriate functional unit	E.1 Textiles with nano-Ag E.2 Façade coatings with nano-TiO_2 E.3 CNTs in electronics
4.3 Life cycle inventory analysis (LCI) 4.3.1 General 4.3.2 Collecting data 4.3.3 Calculating data 4.3.4 Allocation	Clause 6 - LCI data of production of manufactured nanomaterials; Modelling of releases of manufactured nanomaterials	E.1 Textiles with nano-Ag E.2 Façade coatings with nano-TiO_2 E.3 CNTs in electronics
4.4 Life cycle impact assessment (LCIA)	Clause 7 - Assessment of releases of manufactured nanomaterials	E.1 Textiles with nano-Ag E.2 Façade coatings with nano-TiO_2 E.3 CNTs in electronics
4.5 Life cycle interpretation	Clause 8 - Interpretation of LCA with limited information from manufactured nanomaterials	Lessons learnt from the three examples
5 Reporting 5.1 General requirements 5.2 Additional requirements 5.3 Further reporting requirements	Clause 9 - Highlight important aspect when reporting nano-specific LCA	Lessons learnt from the three examples
6 Critical review 6.1 General 6.2 Critical review by experts 6.3 Critical review by panel	Clause 10 - Highlight important nano aspects of critical review	Lessons learnt from the three examples
Annexes (informative)	Annexes A and B	

Three examples are provided as informative text to illustrate the application of LCA to products that contain manufactured nanomaterials. The examples are nano-silver treated textiles [6], nano-enhanced façade coating [7], and CNT enhanced electronics [8]. The selected examples are amongst the most comprehensive LCA studies of manufactured nanomaterials published to date (i.e. mid - 2017). The treatment of uncertainty is discussed in Clause 4 and Annex A. A brief overview of further examples (up to mid-2017) is given in Annex B. The analysis shows the coverage of the studies in a form similar to an earlier study [9].

The illustrative examples are presented in sections corresponding to the same section of the original text in EN ISO 14044:2006 covering "inventory collection", "environmental fate" and "impact assessment and interpretation". They are intended to highlight the particular features relevant to manufactured nanomaterials when included in a LCA. "Fate" in this context refers to the presence in, and transfer through, one or more environments or media (e.g.: air, soil and water) [10].

The presented aspects also include additional, non-published information and data that were particularly useful and illustrative for this guidance document. The status quo of the three examples is summarized in the three sub-sections below. It is noted that that manufactured nanomaterials (MNMs) cover an increasing range of nano-prefixed descriptors, including nano-object, nano-film, nano-fibre and nano-tube. In some cases, or at some points in the life cycle, the MNMs may be in aggregated or agglomerated forms.

Example 1 – "Textiles with nano-silver (nano-Ag)"

The objective of the example is to compare the environmental benefits and impacts of nanosilver treated T-shirts with conventional T-shirts and T-shirts treated with triclosan, a commonly applied biocide to prevent textiles from emitting undesirable odours.

Status Quo: Technical garments have to provide extra features such as enhanced durability or protection for workers; water or oil impermeability for firefighters; or bacterial resistance for adhesive wound tapes, clinical uniforms or sportswear. Silver has known antimicrobial properties and is applied – beside water purification – also to textiles, in order to release toxic ions to kill bacteria. Nanosilver is particularly effective because it can be easily integrated into textile fibres, has higher ion release rates in comparison to the same mass of larger particles and has a longer durability than conventional silver salts. Applied to sports textiles, nanosilver inhibits bacterial growth and therefore reduces unwanted odours. In comparison to other antimicrobial agents for textiles, such as quarternary ammoniums salts or triclosan (now banned in many countries), advanced integration of nanosilver shows less washing-out while exhibiting higher microbial toxicity, based on the same mass. Another advertised property of nanosilver T-shirts is that a lower washing frequency in combination with a lower washing temperature allows saving of resources. On the downside, nanosilver may be harmful to antimicrobial communities in the wastewater treatment plant and may accumulate in the environment over the long term. Moreover, occupational exposure during the production of nanosilver can be elevated in cases when open production systems with poor ventilation are in place. In absence of personal protection measures nanosilver might be inhaled. Nanosilver can enter the deep lung region (alveolar region) and pass across the lung:blood barrier with so far unknown health consequences over the long term. Consumers are less at risk because abrasion tests showed that the probability of releasing free manufactured nanomaterials into the air (followed by inhalation) is minimal. Penetration through intact skin is very unlikely. At the end of life of the nanosilver T-shirts, waste management options that prevent release of manufactured nanomaterials into the environment are preferred.

Scenario analysis allows varying sensitive parameters such as washing frequency and temperature, market penetration and technological maturity to be studied. The scenarios are directly linked to LC inventory data in order to run complete LCA for different possible future states of the system. Nano-specific issues are captured as far as possible and the strengths and weaknesses of the LCA framework regarding the inclusion of nanosilver are discussed.

Example 2 – "Façade coatings with nano titanium oxide (nano-TiO2)"

The objective of the study is to review the Environmental Health and Safety (EHS) impacts of manufactured nanomaterials in paints and coatings used in house building. The latest developments in view of inventory data and impact assessment factors for releases of manufactured nanomaterials are used.

Status Quo: Modern façades of buildings have to meet several functional requirements. These functionalities can influence each other; for example does the commended thermal insulation (related to energy savings and climate change) of a house influence the requirements concerning the outside façade coating and can lead to an increase in the growth of algae and fungi. During their use phase the outside façade coatings are exposed to various impacts such as UV, rain, humidity, heat, temperature differences, air pollution and scratch damage. Indoor façade coatings are also exposed to UV and scratches damage. An integration of manufactured nanomaterials in such façade coatings is expected to hold considerable potential for products that offer improved or novel functionalities during the use phase of these façade coatings and enables in the end the development of materials that fulfil several functionalities at the same time (i.e. so-called multifunctional materials). The manufactured nanomaterials are also expected to optimize some processes during the production of the facade coatings for example by shortening drying time for coatings, and they may also hold a potential for environmental sustainability by saving materials, by substituting hazardous substances, or by improving the durability of the coating.

Three different types of paints containing different types of manufactured nanomaterials (paint A1: nano-TiO_2, paint B1: nano-Ag, paint C1: nano-SiO_2) are compared to the same paints without the added MNMs (paints A2, B2 and C2 respectively). Table 2 summarizes some key data for this study.

Table 2 — Main characteristics of the façade coatings (values based on input from paint industry)

	Paint A1	**Paint A2**	**Paint C1**	**Paint C2**	**Paint B1**	**Paint B2**
MNM integration philosophy	*"Substitution"*		*"Addendum"*		*"Addendum"*	
Application field	Outdoor	Outdoor	Outdoor	Outdoor	Indoor	Indoor
Lifetime [years]	27 [a]	20	27 [a]	20	10 [a]	10
Composition [% w/w]						
— **MNM-content**	3,0	-	5	-	0.3	-
— **Type of MNM**	TiO_2	-	SiO_2	-	Ag	-
— TiO_2**, pigment-grade**	13,58	16,58	-	-	-	-
— **Silicone defoamer**	10,97	10,97	0,3	0,3	0,6	0,6
— **Styrene/acrylic copolymer**	14,62	14,62	23,3	23,3	28,1	28,1
— **Calcium carbonate (filler)**	31,75	31,75	46	46	33,2	33,5
— **Talcum (filler)**	6,58	6,,58	-	-	10,1	10,1
— **Further ingredients**	5,2	5,2	1,7	1,7	2	4,7
— **Water**	11,3	14,3	15,2	28,7	23	23

[a] Assumption (result of a discussion with representatives from the paint industry): in outdoor applications MNM-containing paints have a 30 % longer lifetime; in indoor applications no longer lifetime is assumed.

Example 3 "Carbon Nano-Tubes (CNTs) in electronics"

The objective of this example is to establish a comprehensive assessment of the ecological sustainability of a field emission display (FED) television device by the use of the latest developments in the area of LCA of manufactured nanomaterials (i.e. inventory modelling and impact assessment) in accordance with the EN ISO 14040:2006. In a second step this new technology is then compared to television devices using different versions of current display technologies.

Status Quo: CNTs are cylindrical carbon molecules with novel properties (extraordinary strength, unique electrical properties) and they are efficient conductors of heat, making them particularly interesting for the electronics industry. This material is seen as providing a large opportunity for making a new generation of electronic and electric products – smaller, cleaner, stronger, lighter and more precise. One of the most promising aspects is the unique electronic property of CNT. According to [11], "CNT can, in principle, play the same role as silicon does in electronic circuits, but at a molecular scale where silicon and other standard semiconductors cease to work". Therefore, "Nano" is considered in this industrial sector not only as hype, but to represent a real future potential. Within the electronics sector, displays can be seen as an important interface in machine-based communication among human beings. The area of display technologies has been dominated by the cathode ray tube (CRT) technology since the 1920s – with many different flat panel display technologies being developed since the late 20th century; among them the field emission display (FED) technology. This FED technology can be best compared to the CRT technology, as both of them are based on the principle of a cathode that (in a vacuum) launches electrons towards a glass plate coated with phosphorous. However, whereas in the CRT technology just one such cathode is used, the FED technology uses one individual cathode for each single pixel. In this way, this technology allows the construction of devices with very promising features (e.g. thin, self-emissive screen, distortion free image, wide viewing angle). A great challenge in the FED technology is the issue of micro fabrication of the cathodes in order to have one cathode per pixel; with CNTs being a valuable option for this purpose.

1 Scope

This document provides guidelines for application of Life Cycle Assessments (LCA) of specific relevance to manufactured nanomaterials (MNMs), including their use in other products, according to EN ISO 14044:2006. It does not cover incidental nanomaterials.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN ISO 14040:2006, *Environmental management - Life cycle assessment - Principles and framework (ISO 14040:2006)*

EN ISO 14044:2006, *Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006)*

CEN/TS 17010:2016, *Nanotechnologies - Guidance on measurands for characterising nano-objects and materials that contain them*

ISO 5725-2:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*