ATINER CONFERENCE PAPER SERIES No: ENV2012-0168

Athens Institute for Education and Research
ATINER

ATINER's Conference Paper Series
ENV2012-0168

Nanotechnology Safety Assessment: A Methodology Proposal for Environmental Evaluation

Katia Regina Evaristo de Jesus
Researcher
Embrapa Environment
Brazil

Odílio B.G. Assis
Researcher
Embrapa Agricultural Instrumentation Center
Brazil

ATINER CONFERENCE PAPER SERIES No: ENV2012-0168

Vera Lúcia S. S. de Castro
Researcher
Embrapa Environment
Brazil

Karen Cristina Massini
Post-doctoral Student
Embrapa Environment
Brazil

Carolina de Castro Bueno
Trainee Student
Embrapa Environment
Brazil

ATINER CONFERENCE PAPER SERIES No: ENV2012-0168

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209
Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm

ISSN **2241-2891**
12/09/2012

An Introduction to ATINER's Conference Paper Series

ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. The papers published in the series have not been refereed and are published as they were submitted by the author. The series serves two purposes. First, we want to disseminate the information as fast as possible. Second, by doing so, the authors can receive comments useful to revise their papers before they are considered for publication in one of ATINER's books, following our standard procedures of a blind review.

Dr. Gregory T. Papanikos
President
Athens Institute for Education and Research

This paper should be cited as follows:

Evaristo de Jesus, K.R., Assis, O.B.G., de Castro, V.L.S.S., Massini, K.C. and de Castro Bueno, C. (2012) "**Nanotechnology Safety Assessment: A Methodology Proposal for Environmental Evaluation**" Athens: ATINER'S Conference Paper Series, No: ENV2012-0168.

Nanotechnology Safety Assessment: A Methodology Proposal for Environmental Evaluation

Katia Regina Evaristo de Jesus
Researcher
Embrapa Environment
Brazil

Odílio B.G. Assis
Researcher
Embrapa Agricultural Instrumentation Center
Brazil

Vera Lúcia S. S. de Castro
Researcher
Embrapa Environment
Brazil

Karen Cristina Massini
Post-doctoral Student
Embrapa Environment
Brazil

Carolina de Castro Bueno
Trainee Student
Embrapa Environment
Brazil

Abstract

The investigation of the effects of nanotechnology on the quality of life of the population through level-headed consults to specialists will allow answering relevant questions about environmental effects of nanotechnology and about the use and destination of its products and wastes. We present herein a method for assessing an index of nanotechnology safety based technical parameters. This methodology includes validating the indicators and methods created based on the advice of specialists in nanotechnology and related areas. Therefore, the development of a new approach to assess the safety of the nanotechnologies is an effective mitigatory measure to face the growing challenges pointed out by scientists and legislators concerning environmental degradation, ethical and social issues. The present study aims at creating a methodology for safety assessment of nanotechnologies based on technical data on technology usage from the literature. Those data could be used as a guide to ex ante or ex post evaluations of nanotechnology uses and their effects on the environment.

Acknowledgements: The authors thank National Council for Scientific and Technological Development (CNPq – Brazil) and Brazilian Agricultural Research Corporation (Embrapa – Brazil) for the financial support.

Contact Information of Corresponding author:

Introduction

Nanotechnology is a technology which is indeed widely accepted but not when it is linked to food, and that the attitude to nanotechnology is driven by determinants other than knowledge. Hence, for targeted risk communication it is important to develop strategies that help people to comprehend nanotechnology, to differentiate between the fields of application and to gain an understanding of the cause and effect chains (Simons et *al*., 2009).

In addition, most previous studies that have focused on the regulation of nanotechnology have used descriptive analyses or have tended to focus on normative suggestions for adapting or reforming the existing regulation system. The novel attributes of nanotechnology demand different routes for risk-benefit assessment and risk management, and at present, nanotechnology innovation proceeds ahead of the policy and regulatory environment. Nanoscale structures and nanosystems have the potential to affect not only human health and the environment but also aspects of social lifestyle, human identity and cultural values. The main recommendations for risk-benefit assessment and risk management deal with selected higher risk nanotechnology applications, short- and long-term issues, and global models for nanotechnology governance (Renn & Roco, 2006).

Policy discussions about the social, political, and ethical implications nanotechnology remain limited. There is a high degree of scientific uncertainty about the risks of nanotechnology. In the absence of risk assessment data, decision makers often rely on scientists' input about risks and regulation to make policy decisions. Only recently have social scientists and policy-makers started to pay attention to the social dimensions of nanotechnology research, particularly within the context of how we might regulate it (Corley et *al.*, 2009).

The understanding of potentially risky situations is increasingly multifaceted, which again challenges risk assessors in terms of giving the 'right' relative priority to the multitude of contributing risk factors. Some models were proposed to evaluate nanoproducts. One of them Worst Case Definition (WCD) model, to set up and evaluate the conditions of multi-dimensional risk identification and risk quantification. The model can help optimize risk assessment planning by initial screening level analyses and guiding quantitative assessment in relation to knowledge needs for better decision support concerning environmental and human health protection or risk reduction. The conceptual Worst Case Definition (WCD) model is suggested as a tool that can address the problem of ignorance related to the definition of worst case conditions for risk management of chemicals and nanomaterials. The model focuses on the uncertainty related to the context and concept behind the risk assessment. The two key elements in the method define what to protect in terms of Protected Units (PUs) and how to assess in terms of the Causes of Risk (CRs), respectively (Sørensen et *al.*, 2010).

No clear consensus was reached regarding the classification of nanomaterials into categories to aid environmental studies, except that a chemistry-based

classification system was a reasonable starting point, with some modifications. It was suggested, that additional work may be required to derive criteria that can be used to generate such categories that would also include aspects of the material structure and physical behavior. The physicochemical characterization information identified as important for environmental studies included measures of aggregation/agglomeration/dispersability, size, dissolution (solubility), surface area, surface charge, surface chemistry/composition, with the assumption that chemical composition would already be known. It was also emphasized that the measurement of specific properties, via certain techniques, will sometimes generate an important set of data, rather than an individual value, within the same analysis. Therefore, it is not possible, or desirable, to list a complete or appropriate set of properties that needs to be characterized for each study, without a definition of the aim of the research. In addition properties should be characterized in the test system and not in "the bottle" in which they were supplied.

The prioritization of properties to be determined also implies the need to attach available and suitable methods to measure these properties. Unfortunately this is not always possible, for example, there is no method available to directly measure the specific surface area in an aqueous dispersion of particles. Another relevant example is that there is a high risk of producing biased results with the different sizing techniques available. Environmental matrices such as surface water and soil differ widely in pH and ionic composition, thus agglomeration/aggregation and adsorption, and in turn mobility in the environment, may be predicted if pH dependent stability is described. Similarly, studies on nanomaterial translocation within organisms can also benefit from pH dependent characteristics, as it is well known that pH within an organism varies between organs, tissues and cellular compartments. There is still a deficit of information about how far the limitations of the different methods may influence the correct interpretation of test results, which means that the methods of characterisation and the data interpretation are sometimes a matter of debate (Stone et *al.*, 2010).

Before starting any nanotoxicological study, it is imperative to know the state of the nanoparticles to be used and in particular their size and size distribution in the appropriate test media is particularly important. Particles satisfying standards can be commercially purchased; however, these invariably cannot be used directly and need to be dispersed into the relevant biological media. Often such changes in the environment or ionic strength, or a change in the particle concentration, results in some aggregation or a shift in the particle size distribution. Such unexpected aggregation, dissolution or plating out, if unaccounted for, can have a significant effect on the available nanoparticle dose and on interpretation of any results obtained thereafter (Montes-Burgos et *al.*, 2010).

The Royal Society of Chemistry suggested that 100 nm is the cut-off above which nanoparticles will not enter cells via receptor mediated processes (Royal Society of Chemistry and Royal Academy of Engineering, 2005), and some experimental evidence corroborating this size as a rough guide is emerging

(Chithrani & Chan 2007; Clift et *al.*, 2008). Other important size cut-offs are that particles less than 40 nm can enter the nucleus, while particles less than 35 nm can potentially cross the protective epithelial barriers, such as the blood–brain barrier (Oberdorster et *al.*, 2004). One should be aware that the real size *cut-offs* are dependent on the material and surface details, and these values are at best only guidelines.

Changes in ionic strength and charge screening, or binding of proteins and other biomolecules to the nanoparticles surface can alter their stability in dispersion, leading to partial aggregation, and altered (unknown) concentration of dispersed nanoparticles. Aggregated particles (where the aggregates are long-lived) are no longer available for uptake by cells, and as such, meaningful exposure doses cannot be determined, making dose–response curves unreliable. In addition, many of the commercially available particles differ significantly in terms of their physical properties compared to those specified by the manufacturers (Lundqvist et *al.*, 2008). Thus, poorly characterized samples have the potential to lead to, at best, confusing and, at worst, misinterpreted results. Assessing the potential biological impacts of nanomaterials has become of enormous importance in recent years, as the rapid pace of development of nanotechnology has not been matched by a complete investigation of their safety. The same properties that make nanoparticles exciting for applications, namely their small size, their enormous surface area and their high reactivity, also make them accessible to previously inaccessible locations in living systems with potentially significant consequences for nanomedicine and nanosafety. The large surface area means that they bind proteins and other biomolecules from biological solutions with great efficiency, and with much higher specificity than flat surfaces of equivalent materials (Cedervall et *al.*, 2007). Thus, characterization of the nanoparticle dispersion in the relevant test media is crucial in order to understand the nature of the dispersion actually being presented to the cells, tissue, or organism.

Particles with equivalent diameters below 100 nm are generally distinguished into intentionally produced nanoparticles and ubiquitous ultrafine particles. The literature generally consider as nanomanufactured, particles with diameters ≤100 nm, independent of their source.

The rapid growth in the use of in vitro methods for nanoparticle toxicity assessment has proceeded with limited consideration of the unique kinetics of these materials in solution. Particles in general and nanoparticles specifically, diffuse, settle, and agglomerate in cell culture media as a function of systemic and particle properties: media density and viscosity and particle size, shape, charge and density, for example. When rates of diffusional and gravitational particle delivery are accounted for, trends and magnitude of the cellular dose as a function of particle size and density differ significantly from those implied by *concentration* doses. The simple surrogates of dose can cause significant misinterpretation of response and uptake data for nanoparticles in vitro. Incorporating particokinetics and principles of dosimetry would significantly improve the basis for nanoparticle toxicity assessment, increasing the predictive power and scalability of such assays (Teeguarden et *al.*, 2007).

Environmental impact assessments of engineered nanoparticles require thorough characterization of nanoparticles and their aggregates. Furthermore, quantitative analytical methods are required to determine environmental concentrations and enable both effect and exposure assessments. Many methods still need optimization and development, especially for new types of nanoparticles in water, but extensive experience can be gained from the fields of environmental chemistry of natural nanomaterials and from fundamental colloid chemistry (Hassellov et *al.*, 2008).

Detailed investigations of absorption, distribution, metabolism and excretion remain to be performed on species from the major phyla, although there are some data on fish. The environmental risk assessment of nanomaterials could be performed using the existing tiered approach and regulatory framework, but with modifications to methodology including chemical characterization of the materials being used (Handy et *al.*, 2008).

There are areas of considerable uncertainty associated with characterization of nanoparticle exposure in test systems that apply to all ecotoxicity testing guidelines, except those in which dosing of nanoparticles is oral. These include the way in which the substance is dosed into, and maintained within, the test medium; measurement and characterization of nanoparticles in the test system; better understanding and reporting of abiotic factors that influence behavior of nanoparticles in the test medium; and agreement on how dosimetric data should be reported (Crane et *al.*, 2008).

A set of rapid, cost-effective tests should be agreed between regulators, industry and other stakeholders that are primarily able to demonstrate that a nanoparticle has similar hazard properties to other physical forms of a substance. These might include overall toxicity (e.g., cell viability assay or microbial population growth test to check for specific modes of toxicity that may not be detected by a general toxicity screen, but are relevant for that type of nanoparticle, genotoxicity, immunotoxicity assays, and an oxidative stress assay. A main aim of rapid tests is to establish whether hazard data on demographic endpoints can be read across to nanoparticles from other substances—particularly from macroscale substances to their nano-scale equivalent. If rapid tests are unable to demonstrate that a nanoparticle has similar properties to other physical forms, the demographic effects (survival, growth and reproduction) of that nanoparticle should be measured and should involve both acute and chronic tests on nanoparticle effects until sufficient confidence has been built in the use of assessment factors to extrapolate from acute to chronic effects (Crane et *al.*, 2008).

According some authors (Crane et *al.*, 2008), research on establishing appropriate ecotoxicity test strategies and methods for nanoparticles should focus primarily on defining realistic worst-case exposure scenarios for nanoparticles in the environment and then testing the toxicity of nanoparticles under these scenarios. However, the worst case sometimes not reflects the reality and some potential technology may be not considered to be commercially used based on these results.

Therefore, the development of a new approach to assess the safety of the nanotechnologies is an effective mitigatory measure to face the growing challenges pointed out by scientists and legislators concerning environmental degradation, ethical and social issues. The present study aims at creating a methodology for safety assessment of nanotechnologies based on technical data on technology usage from the literature. Those data could be used as a guide to ex ante or ex post evaluations of nanotechnology uses and their effects on the environment.

Results & Discussion

Nanotechnologies and the Safety-Nanotec Method

The safety assessment of nanotechnology can be a helpful tool in the decision-making process. Search engines and systemized data compression tools, which allow the generation of traceable conclusions, are key elements to assure that the decision-making process culminates in appropriate nanotechnology management, with the best resources and results. The present study proposes a methodological system to evaluate the nanotechnologies safety, providing information organized according to technical parameters from several areas where the effects can be directly or indirectly perceived. The proposed method is based on validated issues or analysis parameters described in previous reports and scientific papers were also considered. The *Safety-Nanotec Method* allows the evaluator to choose specific parameters to evaluate his/her nanotechnology, what enables the analysis of each particular case. Therefore, the nano product or research can be applied in a responsible and sensible way. The information is organized in five analyses: (1) Safety data of the nano product (A); (2) Residual characterization and destination (B); (3) Toxicological characteristics or assessment of the nano product (C); (4) Nano product characteristics (D); (5) Risk perception of the nano product or its application (E). Finally the combination of these five analyses composes the *Safety-Nanotec Index*. Hence, this method allows a reduction in negative impacts and the best use of resources for nanotechnology introduction, what allows the prevention and mitigation of environmental damages. All activities related to commercial release, field trial tests, greenhouse experiments, or even lab assays with nano products can be evaluated by the *Safety-Nanotec Method*. Therefore, the method can be used throughout nanotechnology development, from the new trait search to the regulator assessment for market clearance. Obviously, the exchange of information and experience among all involved parts allows an accurate analysis of nanotechnology safety. The method can be used by program and project evaluators and managers, as well as by regulatory and supervisory agencies.

Worksheets to compile the Nanotechnology Safety Assessment*: the* Safety Nanotec Index

The nano product assessment is composed of safety information that has been already obtained in a laboratory essay or from the literature (Table 1): i) raw material safety data; ii) stability tests of the new product, iii) stability tests of the new feature, iv) evaluation of agronomic applications, v) innocuity tests of the new product (aimed at pharmaceutical or cosmetic products); vi) food safety tests (substantial equivalence), vii) non-toxic ingredients.

$$\sum(Occurrence_{i,vii} \times Stage\ of\ development_{i,vii} \times Result_{i,vii} = Safety\ tests\ (Table\ 1-A)$$

Each weight given to moderation factors will be considered for the generation of the $Safety_{assess}$ *index,* according to the formula below (Tables 2, 3, 4 and 5):

Safety test (A) + Residual characterization and destination (B) + Toxicology characteristics or assessment of the nano-product (C) + Characteristics of the nano-product (D) + Risk perception (E) = Safety Nanotec Index

Tiers of Nanotechnology Safety Index built with the technical impact value

The second tool provides a structure to observe the result of the safety assessment of the nano product (Figure 1). After the tier 1 - safety assessment, the identification of characteristics and impact assessment of the nano product are proceed as tier 2. The safety analysis of its related effects is the final step of the assessment process that consists of reviewing the potential effect and establishing at which level the safety management must take preventive or corrective actions in order to allow an effective and safe use of the nano product.

Figure 1 shows the classes of the Safety Nanotec Index. The illustration of the results of the assessment by dimension (with letters representing each dimension) allows formulating a list of recommendations, aiming at optimizing the nanotechnology safety on each analysis. The level of performance of the technology under evaluation is classified as follows:

(1) Safety assessment: very unfavorable safety evaluation of the nanotechnology – the nano product is not recommended.

(2) Safety assessment: favorable safety evaluation of the nanotechnology – the nano product is recommended.

(3) Safety assessment: very favorable safety evaluation of the nanotechnology - the nano product is highly recommended.

Conclusion

This rapid appraisal allows us to define preventive measures to mitigate or avoid adverse effects or unexpected occurrences from potential or identified hazards. Thus, it is possible to develop and release a nanotechnology with a high probability of success and safety.

The safety assessment proposed here includes parameters that allow estimating the effects of the nanotechnology release in the environment or in human or animal health based on the assignment of quantitative values to several factors correlated with the impact. It results in lower subjectivity and higher clarity in the analysis. Technologies with the same objectives can also be compared using the proposed Method.

Considering the wide variety of nanotechnology products and studies in different development phases to be evaluated, safety concerns must be addressed on a case-by-case basis. The proposed Method may not cover all issues, but it presents a broad approach to safety assessment. There might be always a new and better method that could be used, hence the user is encouraged to expand the possibilities of this tool by adding or deleting indicators according to the kind of technology addressed. Moreover, investors and regulators can evaluate whether the chosen parameters are the best to define the potential impact of the nano product under analysis.

This strategy is very important to a less superficial method that is able to identify which parameters are more strongly correlated with nanotechnology or nanoscience. In addition, characterizing the impact by measuring it with quantitative tools reduces subjectivity drastically. The proposed method represents a less subjective and clearer process for impact assessment than other current processes.

In a nutshell, some efforts from research institutions or governmental agencies could be addressed to define the criteria to develop safety assessment protocols (in a general or a specific way).

The accuracy of the evaluation provided by this methodology results in preliminary technical information that could be the basis to guide the protocol that will contribute for the discussion of a standard regulation process that will guide the rational release and laboratory development of this technology.

References

Simons, J., R. Zimmer, C. Vierboom, I. Harlen, R. Hertel, & G. F. Bol (2009). 'The slings and arrows of communication on nanotechnology.' *Journal of Nanoparticle Research* 11: 1555–1571.

Renn, O. & M. Roco (2006). 'Nanotechnology and the need for risk governance'. *Journal of Nanoparticle Research* 8(2):153–191.

Corley, E. A., D. A. Scheufele & Q. Hu (2009). 'Of risks and regulations: how leading U.S. nanoscientists form policy stances about nanotechnology.' *Journal of Nanoparticle Research* 11:1573–1585.

Sørensen, P. B., M. Thomsen, T. Assmuth, K. D. Grieger & A. Baun (2010). 'Conscious worst case definition for risk assessment, part I - A knowledge mapping approach for defining most critical risk factors in integrative risk management of chemicals and nanomaterials.' *Science of the Total Environment* 408:3852–3859.

Stone, V., B. Nowack, A. Baun, N. van den Brink, F. von der Kammer, M. Dusinska, R. Handy, S. Hankin, M. Hassellöv, E. Joner & T. F. Fernandes (2010). 'Nanomaterials for environmental studies: Classification, reference material

issues, and strategies for physico-chemical characterization.' *Science of the Total Environment* 408:1745–1754.

Montes-Burgos, I., D. Walczyk, P. Hole, J. Smith, I. Lynch & K. Dawson (2010). 'Characterisation of nanoparticle size and state prior to nanotoxicological studies.' *Journal of Nanoparticle Research* 12:47–53.

Royal Society of Chemistry and Royal Academy of Engineering. (2005). *Nanoscience and Nanotechnologies: opportunities and uncertainties (2005)*. London: Royal Society.

Chithrani, B. D. & W. C. Chan (2007). 'Elucidating the mechanism of cellular uptake and removal of protein-coated gold nanoparticles of different sizes and shapes.' *Nano Letters* 7:1542–1550.

Clift, M. J., B. Rothen-Rutishauser, D. M. Brown, R. Duffin, K. Donaldson, L. Proudfoot, K. Guy & V. Stone (2008). 'The impact of different nanoparticle surface chemistry and size on uptake and toxicity in a murine macrophage cell line.' *Toxicology and Applied Pharmacology* 232:418–427.

Oberdorster, G., Z. Sharp, V. Atudorei, A. Elder, R. Gelein, W. Kreyling & C. Cox (2004). 'Translocation of inhaled ultrafine particles to the brain.' *Inhalation Toxicology* 16:437–445.

Lundqvist, M., J. Stigler, T. Cedervall, G. Elia, I. Lynch & K. Dawson (2008). 'Nanoparticle size and surface properties determine the protein corona with possible implications for biological impacts.' *Proceedings of the National Academy of Sciences* 105:14265– 14270.

Cedervall, T., I. Lynch, S. Lindman, T. Berggard, E. Thulin, H. Nilsson, K. A. Dawson & S. Linse (2007). 'Understanding the nanoparticle protein corona using methods to quantify exchange rates and affinities of proteins for nanoparticles.' *Proceedings of the National Academy of Sciences* 104:2050–2055.

Teeguarden, P. M., G. Justin, G. O. Hinderliter, B. D. Thrall & J. G. Pounds (2007). 'Particokinetics In Vitro: Dosimetry Considerations for In Vitro Nanoparticle Toxicity Assessments.' *Toxicological Sciences* 95(2):300–312.

Hassellov, M., J. W. Readman, J. F. Ranville & K. Tiede (2008). 'Nanoparticle analysis and characterization methodologies in environmental risk assessment of engineered nanoparticles.' *Ecotoxicology* 17:344–361.

Handy, R. D., R. Owen & E. Valsami-Jones (2008). 'The ecotoxicology of nanoparticles and nanomaterials: current status, knowledge gaps, challenges, and future needs.' *Ecotoxicology* 17:315–325.

Crane, M., R. D. Handy, J. Garrod & R. Owen (2008). 'Ecotoxicity test methods and environmental hazard assessment for engineered nanoparticles.' *Ecotoxicology* 17:421–437.

Table 1. Safety data of the nano product (A)

Data / tests	Occurrence		Stage of development	Results
			Initial (1)	
	Yes 1	No 0	Advanced (2)	Favorable (+1)
			Conclusive (3)	Unfavorable (-1)
			Not studied (0)	
i) raw material safety data / tests				
ii) stability tests of the new product				
iii) stability tests of the new feature				
iv) evaluation of agronomic applications				
v) innocuity tests of the new product (aimed at pharmaceutical or cosmetic products)				
vi) food safety tests (substantial equivalence)				
vii) non-toxic ingredients				

Table 2. Residual characterization and destination (B)

Residual characterization of the nano product	Yes	No
Conventional or inert residues of the nano product or nanoscale substances	0	-1
Nanoparticle residues of the nano product	-2	0
Localization of the site where the nanotechnological residue will be released	Yes	No
Appropriate destination for the nanoparticle residues	1	-1
Non-specific destination or release of nanoparticle residues	-2	0

Table 3. Toxicological characteristics of the nano product (C)

Ecotoxicological characteristics of the raw material	Weight
Platinum nanoparticles	-3
Metal oxides components in the nano product development	-2
Intermediary group or non-metal component in the development	1
Toxicology assessment of the nano product	Weight
Negative evaluation in vivo tests (birds, aquatic organisms, etc.)	-3
Negative evaluation in vitro tests	-2
The toxicology result corroborates a toxicological description in the literature	-1
The toxicology result is equivalent to an alternative or substitute technology product	0
Positive or inert toxicology result in comparison with alternative or substitute technology product	+1
Abiotic factors	Weight
pH alteration	-1
Water salinity influence	-1
Interaction with other compounds	-2

Table 4. Nano product characteristics (D)

Nano product structure	More than…*	Less than…*
Superficial area of the final nano product	-1	0
Amount of nano product aggregate or spread	-1	0
Size of the nanoparticles or their components	-1 (<40nm)	0 (>40nm)
Nano product characteristics	Yes	No
Unknown chemical properties of the nanoparticles or their residues	-1	0
Adsorption in the surface or in the organisms	-2	0
Solubility	-1	+1
Stability of the nanoparticles	+1	-1
Photocatalysis	-1	+1
Degradation/biodegradation (Inactivation)	+1	-1

**Result in comparison with the non-nanoparticles component / material.*

Table 5. Risk perception of the nano product or its application (E)

Risk perception of the nano product or its application	Weight
Null risk perception (no kind of sues perpetrated against similar technology)	0
Unfavorable risk perception	-2
Benefit perception tested in groups of interest associated with technology use	+2

Figure 1. The Index of the technical assessment is the final step of the *Nanotechnology Safety Assessment*. In this figure the row represents the three classes of the Safety Index.

1	2	3
-20 to 0 Unfavorable safety	*1 to 10* Favorable safety	*11 to 20* Very favorable safety