

## SOME GENERAL CONSIDERATIONS ON "NANO-ETHICS"


### ALCUNE CONSIDERAZIONI GENERALI CIRCA LA "NANO-ETICA"

André JC<sup>1,2</sup>, Frochot C<sup>1</sup>, Nicolas L<sup>2</sup>, Tomei F<sup>3</sup>

<sup>1</sup> LRGP-UMR7274 CNRS-UdL 1, rue Grandville F-54000 Nancy, France

<sup>2</sup> INSIS-CNRS 3, rue Michel Ange F-75016 Paris, France

<sup>3</sup> Department of Anatomy, Histology, Medical-Legal and Orthopaedics, Unit of Occupational Medicine, "Sapienza" University of Rome, Italy

 <sup>1</sup> LRGP-UMR7274 CNRS-UdL 1, rue Grandville F-54000 Nancy, France

<sup>2</sup> INSIS-CNRS 3, rue Michel Ange F-75016 Paris, France

<sup>3</sup> Dipartimento di Anatomia, Istologia, Medicina Legale e Ortopedia, Unità di Medicina del Lavoro, "Sapienza" Università di Roma

**Citation:** André JC, Frochot C, Nicolas L, Tomei F. Some general considerations on "nano-ethics".

Prevent Res 2013; 3 (4): 253-262. Available from: <http://www.preventionandresearch.com/>

**Key words:** nanotechnologies, health risks, ethics, standardization



**Parole chiave:** nanotecnologie, rischi per la salute, etica, standardizzazione

## Abstract

The emerging area of nanotechnologies possibly offers promise for the future with its focus on preventive design. To gain traction, however, it is important that research on the sustainability of materials is funded at levels significant enough to identify early warnings, and that possible responsible regulatory systems provide incentives for safer and sustainable materials during the life cycle of materials and systems. The concept of protecting human health and integrity is accepted by all. The rules by which society tries to achieve this humanist objective are relative to a given cultural situation in a specific space and time. The relationship between the individual and the collective human society is not only a matter of ways of living together; it is intimately linked with societal norms which are discussed in this essay. In this respect, for ethical reasons, the authors propose to "invent" a "precautionary" standardisation, progressive yet accepted by the "global village", in order to avoid nano-errors?

## Abstract

L'area emergente delle nanotecnologie forse offre valide promesse per il futuro grazie alla sua attenzione sulla progettazione preventiva. Per guadagnare consensi, tuttavia, è importante che la ricerca sulla sostenibilità dei materiali sia finanziata a livelli sufficientemente importanti tali da identificare precocemente i pericoli, e che i possibili sistemi di regolamentazione responsabili forniscano incentivi per l'adozione di materiali più sicuri e durevoli per il ciclo di vita dei materiali e dei sistemi. Il concetto di protezione della salute e l'integrità umana è ormai accettato da tutti. Le regole con cui la società cerca di raggiungere questo obiettivo umanitario sono relativi a una determinata situazione culturale spazio-tempo specifica. Il rapporto tra l'individuo e l'intera società umana non è solo una condizione di vita in comune; esso è intimamente legato alle norme sociali che sono discusse in questo saggio. Sarà per questo motivo, per ragioni etiche, che gli autori propongono di "inventare" una standardizzazione "preventiva", progressiva ormai accettata da parte del "villaggio globale", al fine di evitare nano-errori ?

"No society can survive without a moral code based on values that are understood, accepted and respected by the majority of its members. That's all there is to it. Can modern societies master indefinitely the fantastic powers that science has given them on the criterion of a wave of humanism coloured by a sort of optimistic and materialistic hedonism? Can they, on this basis, resolve their intolerable tensions? Or are they going to crumble?" (1).

Nanotechnology development has occurred in the absence of clear design rules for engineers, physicists, chemists and materials developers on how to integrate health, safety and environmental concerns into design. The emerging area of "green nanotechnology" possibly offers promise for the future with its focus on preventive design. To gain traction, however, it is important that research on the sustainability of materials is funded at levels significant enough to identify early warnings, and that possible responsible regulatory systems provide incentives for safer and sustainable materials during the life cycle of materials. "Nanomaterials now represent a major economic and societal challenge on account of the possibilities of the innovations of rupture that they represent in a great many areas of our day-to-day life, including health, energy, the environment, information and transport, all the while staying within the bounds of the principles of Sustainable Development" (2). This assertion is followed by comments issued from OECD Report (2013) (3) in which the nanotechnologies are presented as: "Nanotechnology is the latest in a long series of technologies heralded as ushering in a new era of technology-driven prosperity. Current and future applications of nanotechnology are expected to lead to substantial societal and environmental benefits, increasing economic development and employment, generating better materials at lower environmental costs, and offering new ways to diagnose and treat medical conditions. Nevertheless, as new materials based on nano-scale engineering move from the lab to the marketplace, have we learnt the lessons of past 'wonder technologies' or are we destined to repeat past mistakes?" (4). These remarks, elements of the foreword of a French Ministry of Industry report, are in unison with many international-level prospecting reports as well as with national and/or European research programmes (ie.cf. 6th and 7th FWP or H2020).

Like the new information and communication technologies, nanotechnologies and their products, nano-materials, are transversal, likely to reach most economic and industrial activities, and contagious as they irrigate neighbouring technologies (5). There is both a deepening and a widening, resulting probably, at the end of the line, in a loss of perception of the relationships between cause and effect in the act of production. All the new and increasingly complex techniques, which are appearing more and more quickly (cf. Moore's law in information technology – a doubling every 18 months) and more or less simultaneously, naturally upset the relationships between technology, the economy and society: economic performance, employment, quality of life, and... risks for the environment, including that of work. The economic stakes are high (potential world market of over 300 billion Euros in 2010, doubling every 3 years)(2) and the research effort, both national and European is undoubtedly not up to the expectations and hopes of enterprises and states.

Recent syntheses undertaken by various bodies (6-24) illustrate the real potentialities of human risk, carbon nano-tubes being one example. Yet, in the meantime, Europe has taken the initiative of standardising nanotechnologies. According to (2), this involves consolidating the dialogue between industrialists and administrations in order to contribute to the industrial development of nano-materials.

In this normative project, the health, safety and environment component is a priority, particularly for France (cf. One of the first AFNOR meeting of 10 June 2005, The French organization in charge of standardization at National level). This concern is naturally laudable, but the question raised by the author is whether the scientific knowledge concerning the risks linked to nano-materials is sufficient at the present time to define consistent criteria to further develop a technical point of view while protecting citizens (and therefore also operators) and the environment. The context of uncertainty must furthermore be emphasised as the compound word nano-materials, a genuine carryall word, characterises a set of materials that have as their unifying property a very high surface to volume ratio, which sets them apart from solid materials.

The contention of the authors is that new consideration must be given to standardisation in the uncertain, and therefore to the associated ethics, whether this is undertaken at European (European Committee for Standardisation) or international (ISO) level. E. Kant in "a critique of pure reason" raises simple principles:

- What can I know? a domain typically entrusted to researchers;
- What must I do?
- What can I hope for? (cf. all the prospecting reports on the subject).

The second question of Kant in fact echoes that of the authors, namely how science, technology and society manage their relationships with a view to progress. How, in a world undergoing profound change (and not entirely caused by

nanotechnologies), can actions be proposed to bridge the gap between values (enterprises and societies)? Which actors must authorise this coherence building? What is their legitimacy based on? How (and by whom) will their actions be assessed? Should privileged links be established between the participating parties which could reveal their areas of agreement, their dissension, etc.? At the end of the day, how can a system be developed where innovation can be legitimised by work that the collective conscience will accept as being useful for mankind? And each knows that the Fordian system in given up the step in the new economy. This one explores variety and reactivity with new criteria of high quality, innovation, renewal to represent one of the predominant criteria of competitiveness (25). In this context of strong temporal pressure, risks and ethical aspects are in general taken into account only inside regulation in force.

The concept of protecting human health and integrity is accepted by all (26). The rules by which society tries to achieve this humanist objective are relative to a given cultural situation in a specific space and time. However, can it be said, in an age of accelerated socio-technical evolution, that the rules and standards, afflicted by considerable uncertainties, still constitute a guaranteed reference? How are trust and technological progress to be reconciled? Is it not necessary to redeploy the idea of progress that is overly shapeless to another basis, better anticipating the (possible) harmful effects of new technologies? Must we not get back to the concepts of the ethics of responsibility of H. Jonas, who wrote (27, 28):

- "Act in such a way that the effects of your action are compatible with the permanence of authentically human life on Earth;
- Act in such a way that the effects of your action do not destroy the future possibility of such life;
- Do not compromise the conditions for the indefinite survival of humanity on Earth;
- Include in your current choice the future integrity of Man as a secondary objective of your wish".

In this respect, the knowledge demanded has a dual origin, objectively knowledge of physical causes, subjectively knowledge of human goals, which requires us to enhance our forecasting of knowledge. However, the example of health risks highlights very long-term effects on humans and on the environment, imposing brutal modifications to processes and human and social costs considered unacceptable (mad cow illness, silicosis, asbestos problems, etc.) (29).

Whatever the case, communication on the actions is vital. Indeed, there is an affective connotation of risk which, over time, takes on a considerable political dimension (up to safety ideology) (30), that is heightened by the media. However, as pointed out by Sousa (31), "emotion, by momentarily limiting the field of our attention pushes us, quite naturally, to ignoring the majority of the information at our disposal".

In this context of complexity and temporal pressure, no one discipline examining the risks linked to nanotechnologies can fully explore a subject alone. "Or, indeed, researchers treat the subjects in a partial manner, ignoring or covering all the links that inevitably exist between this partial view and any overall preconceptions that they must surely have on the subject. Or, indeed, they place their preconceptions at the heart of the scientific investigation – not as elements interesting to look at, but as the driving forces of a dynamic that then takes on the inevitable desire for unity as a footstep towards what becomes a requirement of unity (...):

- Integrated thought on the subject and its facets;
- Application of specific intellectual lines required simultaneously;
- Thought on the limits attached to any specific intellectual line;
- Requirement of coherence.

(In this sense), the interdisciplinarity (to be applied) cannot constitute a hazardous or vague mixture or resemble a simple process of fusion, and thus of neutralisation" (32).

This principle of openness, laudable in itself, does not fall within the «ordinary» framework of scientific research, corresponding more to an expert approach and often occurring in a context of scientific uncertainty. In an undoubtedly simplistic way, there is a shift from objective risks to a "certain imagination" of risks: on the one hand, accepted probabilistic logic (current situation), and on the other, a heuristic approach; there can thus be a shift from an appraisal of safety to the search for a feeling of safety. Besides, how can sense be made of prevention actions based on scientific knowledge if the causalities are no longer perceptible?

But, "because scientific knowledge would exponentially increase, the most part of the researchers ceased thinking of scientific unification. Since their theories are included in general paradigms, no need to search farther (...). The great majority of the scientists have always been only gold-diggers paid day by day. It is even truer today. They accept

necessary training to reach on the border of their explored lands and make their discoveries as quickly as possible there, because the life in these regions is costly and risked. The scientists, working in several million dollar laboratories, have no time to imagine the slightest global vision and they see besides not the benefit which they could draw from this view" (33, 34). It is not therefore this scholars' body that it is possible to trust for advising the Society... (35). Indeed "Professors became highly attuned to the institutional priorities of various founding agencies – often at a cost to their own creativity and desired research directions" (36). At the same time, Isabelle Stengers (37) amplifies the purpose: she writes: "Let us not make a mistake there, today a large part of scientific expertise has as role to make hush up about the anxiety of opinion, to inform the public that it makes a mistake and that it is unable of this objective judgment which is the privilege of the scientists"! Then, whom to trust? In the competent people interest of which is elsewhere or to the not informed public? Since they tend to leave the place in secular conservative knowledge, made legitimate by absence of credible scientific opinions, how will they be able to manage polemics and controversies? How to manage the difference of nature between science and opinion? (38, 39). "The construction of the understanding of the problem can also be the object of steps of de-confinement during which its definition is called into question and, be the object of an opening of intellectual games, then re-confinement when takes place a stabilization of its definition and actors' systems in charge of its management" (40).

Anyway, one of the first ways is to reduce uncertainty by employing a model accepted by society (hence the risk of "tectonics of paradigms", leading for example to ideological confrontations). A second undoubtedly concerns the increase in the number of researchers but, account taken of the context, there will be a need to develop actions on weak signals, on uncertain objectives (look where?) often linked indirectly to the problem to be dealt with. These must take into consideration, besides the "hard" sciences, other «softer» knowledge: sociology, risk acceptability, etc. (41). In this respect, it is becoming increasingly difficult to define the difference between the "good" and the "bad" on account of the very considerable increase in interdependencies, not only within the work context but also with the social body as a whole.

The question "what is bad?" which is raised, finds a response proposed in (42): "what stretches philosophy to the limit"! Is this enough? Porée reminds us (42): "Thus, just as virtue consists in science, vice consists in ignorance: it [the bad] is the effect not of a positive willingness to do badly but of a powerlessness to see what should be done". However, we are under the sign of perpetual change. Movement "goes ahead according to a law which is unique to it and which, in the long term, cannot be stopped" (43). It is therefore impossible to stabilise scientific knowledge, with the risk of irreversible problems. However, "in societies where tradition dominates, the reference points are both fixed and determined. The hierarchy imposes its references (...). The general upheaval that we have to face places us in new, unforeseen and non-coded situations" (44).

Can the problem be solved? Dupuy and Roure (45) point out that "nanotechnologies open up a vast area that man must be able to standardise if he wants to give them meaning and finality. The human subject has to resort to extra willingness and conscience to determine not what he/she wants to do but what he/she must do". But how?

### **And the precautionary principle?**

Oppenheimer wrote in 1948, in relation to the military use of nuclear energy, that "physics has known sin" (46). The transition which is starting to emerge is causing substantial changes both in innovation and in the process of risk acceptability. "Yesterday, scientific activity could still develop, with the risk of being deemed guilty of or of being an accomplice in disastrous consequences. Today, we are not far from asking it to put forward proof of its innocence" (47). It is therefore necessary to rebuild the trust between science, technology and society.

"Answer reassures, question puts in anxiety. In the literal sense of term, it obliges in movement, in creativeness. To open a question, it is necessarily to force to move look, to re-question hypotheses, to see again rules, to hunt out the concealing (48). By going out of existent frames by forcing the experts to go out of their own territories, there is risk of creating at these last of deep anxiety (49). Besides, according to (50), scientists can agree to close eyes to be the "kings of day" by alerting a posteriori and proclaiming that they represent the public common good. Once again in whom to confide? However, as Duby (51) reminds us: "a risk is all the more overestimated and causes even more fear the more it is unknown, the more it is not mastered or rather that there is a feeling that it has not been mastered, the more that individuals are exposed to it unwillingly, and the more it is due to an artefact, i.e. that it has been created by man and does not exist in nature". Maybe this reflection can be applied to nanotechnologies?

Articles have been published in many media outlets and rumours abound. This context raises the question of the use of the normative means used until now based on knowledge and technical criteria, validated by long experience. It is on the basis of this observation that the precautionary principle was designed "entirely driven by a new urgency of decision" (36, 52), a new legal resource that expresses a model of «social anticipation» to consider and deal with uncertain risk. The intention of this essay is not to return to the basics of the precautionary principle, recently introduced into French law and accepted by many other Countries. A problem can be dealt with in different ways. Two issues must however be considered: the emergence of the question and the amplitude of the problem. In the latter context, must the action be at local or world level? In the absence of scientific knowledge on the risks, must the brakes be put on research in the area in one country, but not in others? Hence, the interest in standardisation, undoubtedly to be revisited, valid at planetary level.

Thus, like standardisation, the precautionary principle is a means. It can be exploited provided that we are able to adopt effective and proportional measures aimed at preventing the risk of serious and irreversible damage to the environment at an economically bearable cost (53). Firstly, the quality of the experts and how they are chosen must be beyond reproach.

The implementation of a procedure of expertise is a means to exceed the multiplicity of points of view by substituting for it, honestly, an unequivocal vision of put down question (54). But, how is that possible? "The idea of a responsible scientist able of answering consequences of what its science allows to envisage is a poor idea, because the non-reliability, outside the laboratory, of its modes of abstraction that must be firstly asserted"! If Isabelle Stengers is right (37), it becomes difficult to advance in a serene expertise leading to a responsible ethics. In this context, Benamounzig et al (55) consider that it exists between research and industry some links of dependency which are inertial factors in action, what weighs down the difficulty in acting to the society benefit. Sometimes, they are funding effects on results leading to science instrumentation for biased expertise (56). Especially when operating in a context of high uncertainty, the expert approach is necessarily heuristic (and mostly interdisciplinary) (41, 57). But, an intercultural contact does not automatically breed mutual understanding. Rather, it confirms the groups involved in their own identities and prejudices... The nature of understanding problems depends on both the sending and the receiving culture; language plays a crucial role in intercultural interactions (30). However, Chemarin et al (58) consider that uncertain information is even more reliable when it includes an adequate and coherent theoretical core backed up by a broad and diversified scientific community. The debate therefore remains open.

Secondly, it is also necessary «to guarantee the conditions of legitimacy of a decision whose morality can no longer be measured against its appropriateness to a preordained content: its role is to institutionally guarantee the establishment and execution of consultation procedures during which no-one can claim to hold the key to the truth» (59). However, how can information be gleaned about the uncertain if all the choices are presented as stemming from inescapable changes? (6-24, 60). Remaining on the sidelines falls within the sphere of a certain form of technical (and consequently social) suicide; the hopes of researchers are furthermore turned towards accessing new knowledge than towards determining (often difficult) the long-term health effects of new technologies.

### **What is to be done?**

"The relationship between the individual and the collective human society is not only a matter of ways of living together; it is intimately linked with societal norms (in the sense of value systems of major groups of the population). It therefore affects both people's mental programming and the structure of functioning of many institutions aside from the family: educational, religions, political, and utilitarian" (49). In fact, the problem is the extent of the situation, its rapidity of establishment, and therefore its associated potentially irreversible character. The principle of enlightened standardisation (cf. supra) can be envisaged and must guarantee the sustainability aspects put forward by Derian (2). The framework must naturally embrace the traditional concepts involved in this type of situation: metrological approach, studies on animals (toxicity, etc.), prevention measures, etc., but also, in conditions where the information is not stabilised, associate other actors. It is probably at this stage that the ethical context and its application in the form of a standard may be encountered. "Morality is not a check-list or a group of rules to be applied as a prescription or a recipe of cuisine. The ethics needs specific methodologies of inquiries and fixing things: methods of inquiries to spot difficulties and problems to be solved, methods of fixing things to draw up plans to be used as working hypotheses to resolve spotted problems" (61).

However, if we examine the arsenal of «traditional» chemical risk based on methods that have been validated for a long time, it still cannot be considered that all the risks have now been mastered (cf. for example the REACH approach, etc.). Besides, in the exponential context of the development of nanotechnologies, it can be considered that we are far removed from the situation of chemistry and solid materials! And this is even truer the closer one is to the design process! How can the toxicology of a nano-material be studied when it has not yet been produced? Can we rely on the knowledge that we have of solid material? Even if this were true, is it transposable to another material? Etc.

"When disruptive change appears on the horizon, managers need to assemble the capabilities to confront the change before it has affected the mainstream business. In other words, they need an organization that is geared toward the new challenge before the old one, whose processes are tuned to the existing business model, has reached a crisis that demands fundamental changes" (62).

How then can safety be encouraged without having a negative impact on innovation? The preventive approach within a research or R&D laboratory must be applied: training of those directly involved in the risks, information about the modes of collective and even personal protection. However, risk is considered to be the product of danger by exposure. The domain of prevention has moulded social areas, legitimising practices aimed, when the hazard is known, at lessening the risk by reducing exposure. Inside the enterprise or research laboratory, there is a need to make people aware of a potentially high at-risk activity and that the prevention "toolbox" can be exploited provided that good and validated means of prevention are available.

In addition, at the heart of production, there is a possibility – at a relatively low cost (?) (Adaptation of current processes) – Of preventing operator exposure. The use of nano-materials in complex processes can also be the subject of the same type of protection. Although the health of employees can therefore normally be guaranteed, the use of the materials distributed to end users should be adapted to minimum exposure in the environment (waste management, etc.) before toxicological and even epidemiological studies confirm the absence of health risks.

However, toxicological studies, still insufficient in numerical terms, are somewhat alarming (63): new properties caused by the reduction in the size of the particles can indeed be expected. These could lead to risks that solid materials do not have. Thus, the field of the scientific uncertain in a temporally constrained situation requires a reanalysis of the «sustainable» methods to be employed in the development of new processes. The example of nanotechnologies, an area in full expansion, can be used to examine what must be done, research, and how to have greater discernment about the actions to be undertaken, which can only be in conjunction with society.

Whatever the case, operator information and training is necessary, as is efficient protection. This context therefore imposes research on the most appropriate processes to prevent their exposure. However, after (before?), production will raise the problem of the possible risk of exposure during the life cycle of the material (as well as at the time of its recycling, etc.).

The central question is to match (and to further develop) these general proposals with practice in a framework where the return on investment does not substitute all moral argumentation (63). However, "it is more economic to design and introduce prudence systems at the same time as the processes themselves whenever this is possible. Nevertheless, we stumble collectively on the unavailability of the results of impact studies, on the absence of characterisation of the risks, on the difficulty in grasping their nature, their insurance or legal financial compensation, and on the flagrant shortcomings of adequate conceptualisation" (45).

"Political decision-makers have yet to address many of the shortcomings in legislation, research and development, and limitations in risk assessment, management and governance of nanotechnologies and other emerging technologies. As a result, there remains a developmental environment that hinders the adoption of precautionary yet socially and economically responsive strategies in the field of nanotechnology. If left unresolved, this could hamper society's ability to ensure responsible development of nanotechnologies" (3). Must we not then look again at the traditional decision-making processes by associating other actors to broaden the scope of the debate? Why then not invent a "precautionary" standardisation, progressive yet accepted by the "global village", to avoid nano-errors?

"This is why to state (...) that ethics is a chance is to recognise that despair is one too" (64).

## References

1. Monod J. Pour une éthique de la connaissance, La Découverte, Paris, 1970.
2. Ministry of the Ecology and Sustainable Development. (2006). Nanotechnologies, Nanoparticles: What Hazards – What Risks?  
Available on line from: [http://www.developpement-durable.gouv.fr/IMG/pdf/CPP\\_NanotechnologiesNanoparticles.pdf](http://www.developpement-durable.gouv.fr/IMG/pdf/CPP_NanotechnologiesNanoparticles.pdf)
3. EEA, European Environment Agency. (2013). Late lessons from early warning: Science, precaution, innovation.  
Available on line from: <http://www.eea.europa.eu/publications/late-lessons-2>
4. Klein E. Le Small-Bang des nanotechnologies, O. Jacob, Paris, 2011.
5. André JC. Réflexion sur les risques émergents au travail. Le Banquet 2005 ; 22: 307-316.
6. Mark D. President MD. (2004). Nanomaterials: a risk to health at work? Available on line from: [www.hsl.gov.uk](http://www.hsl.gov.uk)
7. BIA, Berufsgenossenschaftliches Institut für Arbeitsschutz. (2003). Ultrafine aerosols at workplaces. Available on line from: <http://d-nb.info/973093706/34>
8. SCENIHR, Scientific Committee on Emerging and Newly Identified Health Risks. (2006). The appropriateness of existing methodologies to assess the potential risks associated with engineered and adventitious products of nanotechnologies. Available on line from:  
[http://ec.europa.eu/health/ph\\_risk/committees/04\\_scenih\\_r/docs/scenih\\_r\\_o\\_003b.pdf](http://ec.europa.eu/health/ph_risk/committees/04_scenih_r/docs/scenih_r_o_003b.pdf)
9. SCENIHR, Scientific Committee for Emerging and Newly-Identified Health Risks. (2007). The appropriateness of the risk assessment methodology in accordance with the Technical Guidance Documents for new and existing substances for assessing the risks of Nanomaterials. Available on line from:  
[http://ec.europa.eu/health/ph\\_risk/committees/04\\_scenih\\_r/docs/scenih\\_r\\_o\\_010.pdf](http://ec.europa.eu/health/ph_risk/committees/04_scenih_r/docs/scenih_r_o_010.pdf)
10. SCENIHR, Scientific Committee for Emerging and Newly-Identified Health Risks. (2009). Risk Assessment of Products of Nanotechnologies. Available on line from:  
[http://ec.europa.eu/health/ph\\_risk/committees/04\\_scenih\\_r/docs/scenih\\_r\\_o\\_023.pdf](http://ec.europa.eu/health/ph_risk/committees/04_scenih_r/docs/scenih_r_o_023.pdf)
11. HSE, Health & Safety Executive. (2003). In vitro determinants of particulate toxicity: the dose-metric for poorly soluble dusts. Available on line from: <http://www.hse.gov.uk/research/rrpdf/rr154.pdf>
12. Roco MC. Nanotechnology Research Directions for Societal Needs in 2020. Science Policy Reports 2011; 1: 1-28.
13. Friedlander SK, Pui DYH. Emerging issues in nanoparticle aerosol science and technology, University of California, Los Angeles, 2003.
14. National Academy of Sciences. A Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials, The National Academy Press, Washington, 2012.
15. Dürrenberger F, Köck J, Höhener K. Overview of completed and ongoing activities in the field: safety and risks of nanotechnology, Report Technology Management, Switzerland, 2004.
16. E.U. (2004). Nanotechnologies: a preliminary risk analysis on the basis of a workshop organized in Brussels. Available on line from: [http://europa.eu.int/comm/health/ph\\_risk/event\\_risk\\_en.htm](http://europa.eu.int/comm/health/ph_risk/event_risk_en.htm)
17. Parizeau MH. Biotechnologie, nanotechnologie, écologie : entre science et idéologie, Quae, Paris, 2010.
18. Hansen SF, Larsen BH, Olsen SI, Baun A. Categorization framework to aid Hazard Identification of Nanomaterials. Nanotoxicol 2007; 1: 243–250.
19. Hansen SF. Regulation and risk assessment of nanomaterials: Too little, too late?, Department of Environmental Engineering, Kgs. Lyngby, 2009.
20. Maynard AD. Regulators: Don't define Nanomaterials. Nature 2011; 475: 31.
21. Maynard AD, Warheit D, Philbert MA. The New Toxicology of Sophisticated Materials: Nanotoxicology and Beyond. Toxicological Sciences 2011; 120 (1): S109–S129.
22. Maynard A, Rejeski D. Too small to overlook. Nature Nanotechnology 2009; 460: 174.
23. ISO, International Organization for Standardization. Nanotechnologies — Terminology and definitions for nano-objects — Nanoparticle, nanofibre and nanoplate, ISO/TS 27687:2008, Geneva, 2008.
24. Hervé-Bazin B. Nanoparticules; un enjeu majeur pour la société au travail, EDP Sciences, Paris, 2007.
25. Lipowetsky G. Le Bonheur paradoxal; essai sur la société d'hyperconsommation, Gallimard, Paris, 2006.
26. Didier C. Penser l'éthique des ingénieurs, PUF, Paris, 2008.
27. Jonas H. Le principe Responsabilité, Cerf, Paris, 1990.



28. Jonas H. Pour une éthique du futur, Payot, Paris, 1998.
29. Le Marec J. Les études de science: pour une réflexivité institutionnelle, EAC, Paris, 2010.
30. Le Breton D. La sociologie du risque, PUF, Paris, 1995.
31. de Sousa R. Evolution et rationalité, PUF, Paris, 2004.
32. Alvarez-Pereyre F. L'exigence interdisciplinaire, MSH, Paris, 2003.
33. Wilson EO. L'Unicité du savoir, Robert Laffont, Paris, 2000.
34. Heil C. De la science à la technoscience, du chercheur au technologue, PhD Thesis Evry University, Val d'Essonne, 2010.
35. Claessens M. Allo la science? Analyse critique de la médiacience, Hermann, Paris, 2011.
36. Quake S. Guest column: Letting scientists off the leash, New-York Times Newspaper, New-York, 2009.
37. Stengers I. Une autre science est possible! Manifeste pour un ralentissement des sciences, Les empêcheurs de penser en rond, Paris, 2013.
38. Bensaude-Vincent B. La science contre l'opinion; histoire d'un divorce, Les empêcheurs de penser en rond, Paris, 2003.
39. Bloor M. La maladie du poumon du mineur et les usages instrumentaux de l'expertise. Alkirsch M, Barthe Y and Rémy C, Sur la piste environnementale: menaces sanitaires et mobilisations profanes. Mines-Paritech, Paris, 2010.
40. Gilbert C, Henry E. Comment se construisent les problèmes de santé publique, La découverte, Paris, 2009.
41. André JC, Masse R. L'expertise, la science et l'incertitude: l'expertise scientifique ou la langue d'ESOPE? Environnement, risques et santé 2002; 1: 299-306.
42. Porée J. Le mal – Homme coupable, Homme souffrant, A. Colin, Paris, 2000.
43. Arendt H. Le système totalitaire, Seuil, Paris, 1972.
44. Etchegoyen A. Le temps des responsables, Julliard, Paris, 1993.
45. Dupuy JP, Roure F. Les nanotechnologies: éthique et prospective industrielle, Report au conseil général des mines et au conseil général des technologies de l'information Ministère de l'Industrie, Paris, 2004.
46. Oppenheimer JR. Physics in the Contemporary World. Bull Atomic Scientist 1948; 4 (3): 65-68.
47. Salomon JJ. Les frontières du progrès. Passages 1999; 93 :44-49.
48. Lagadec P. Du risque majeur aux mégachoses, Préventique, Bordeaux, 2012.
49. Hofsted G. Cultures consequences, Sage Pub, Thousand Oaks, 2001.
50. Bronner G, Géhin E. L'inquiétant principe de précaution, PUF, Paris, 2010.
51. Duby JJ. L'excès de jurisprudence, générateur de risque et de peur et donc d'auto-enfermement chez les scientifiques. Passages 1999; 93: 34-35.
52. Latour B. Le Monde Newspaper 04/01/2000, Paris, 2000.
53. Barnier, French Law 02/02/1995, Article 200-1 rural code, Paris.
54. Bouillon JL. L'expertise scientifique en société: regards communicationnels, Hermès, Paris, 2012.
55. Benamouzig D, Borraz O, Jouzel JN, Salomon D. Contribution opérationnelle des sciences humaines et sociales à l'expertise en santé – alimentation – environnement – travail, R&D Contract Report 2010-CRD-18 ANSES, Paris, 2013.
56. Foucart S. La fabrique du mensonge; comment les industriels manipulent la science et nous mettent en danger, Denoël-Impacts, Paris, 2013.
57. Roqueplo P. Entre savoir et décision, l'expertise scientifique, INRA, Paris, 1996.
58. Chemarin S, Henry C, Michel-Kerjean E. Incertitude, précaution et assurabilité" Report au commissariat général au plan, Ministère de l'Industrie, Paris, 2002.
59. Hunyadi M. Survivre à la science – une certaine idée du futur, Michel A, Paris, 1999.
60. Legoff JP. La démocratie post-totalitaire, La Découverte/Poche, Paris, 2003.
61. Dewey J. Reconstruction en philosophie, Presses Universitaires de Pau – Pau, 2003.
62. Christensen CM. The innovator's dilemma, Harper Business, New-York, 2003.
63. Etchegoyen A. La valse des éthiques, Bourin f, Paris, 1991.
64. Audi P. L'éthique mise à nu par ses paradoxes mêmes, PUF, Paris, 2000.

**Corresponding Author:** Jean-Claude André

INSIS-CNRS, 3 rue Michel Ange F75016 Paris - France

LRGP UPR 3349 CNRS - University of Lorraine – 1, rue Grandville F54000 Nancy - France

e-mail: [info@preventionandresearch.com](mailto:info@preventionandresearch.com)



**Autore Corrispondente:** Jean-Claude André

INSIS-CNRS, 3 rue Michel Ange F75016 Paris - France

LRGP UPR 3349 CNRS - University of Lorraine – 1, rue Grandville F54000 Nancy - France

e-mail: [info@preventionandresearch.com](mailto:info@preventionandresearch.com)