# Institutionalization of Safe by Design vs. Scientists Responsibility

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## Abstract

Relying on several waves of field surveys, this paper shows how the French protests against nanotechnology led to a bifurcation in scientific research practices. In France, these protests rose rapidly after the launch of major scientific and technological programs. It took virulent forms that questioned the very legitimacy of academic research, whereas this had not been the case in the context of the anti-nuclear protest, which focused on power plants. Having to face these protests, academic research practices were pushed to evolve, with the characteristic of taking into account environmental and health risks in disciplines such as physics and chemistry, that were previously largely self-referential. Academic research has thus had to respond to the need to assess the risks associated with 'nano' products by progressively referring to the notion of 'safe by design', i.e. safety as soon as nanomaterials are designed. However, this consideration of the question of risks raises formidable problems. These problems may be cultural or institutional, due to the lack of an interdisciplinary tradition, or scientific, given the complexity of the obstacles to overcome in order to design safe nanomaterials. However, the need expressed by industry for risk assessment methods for nanomaterials appears to be a powerful lever for transforming academic practices.

Keywords: Citizenship; Ecology; Nanotechnology; Research; Risks;

## Introduction

The academic literature has highlighted the conditions for the emergence of the notion of "safe by design" (Kelty, 2009) as a possible solution to the controversies and civic protests generated by "nanotechnology", forcing the scientific community to evolve its relationship with technological risks. This solution appears to be a response to the controversies that have developed since the launch of the major "nanos" programs in many countries.

Safe by Design offers an opportunity to overcome the problems raised by the divergence between scientific disciplines focused on the design of nanotechnology and scientific disciplines focused on risk assessment (Mikael Johansson & Åsa Boholm 2017): the former are focused on scientific and technological development, while the latter operate, de facto, as brakes on this development. On the other hand, safe by design is likely to respond to the civic critique of nanotechnologies, at least to that relating to environmental-health risks.

We will show how the contestation has moved research through the integration of risk problems in the design of nanos, and how this evolution leads to a redistribution of the relationship between researchers and industry.

## 1. Questioning the legitimacy of scientific research

With nanotechnology and, by extension, nanosciences, civic protests have taken a turn since there has been an increase in the number of associative demands for a moratorium, at least on applied research or, even, on all research, including academic research, related to nanos (Suraud et al., 2011).

Unlike the proposal by researchers in 1975 for a moratorium on genetic manipulation, the demands for a moratorium on nanos have created a strong divide between, on the one hand, academic researchers (mainly in physics and chemistry) and, on the other, citizen associations opposed to the nanotechnology development programs, in France and in the European Union.

This contestation of the legitimacy of nanotechnology research can be interpreted as a new politics "of" scientific research in the sense that research appears as a renewed political issue. Certainly, old discussions have already questioned the relationship of science to power (Habermas 1990/1973), and Ulrich Beck had already indicated that science must pass political tests (Beck 2001/1986). The widespread but flexible diffusion of the notion of technoscience illustrates this intertwining of research with political and economic issues. Most of the works on this subject have thus been oriented towards highlighting a tendency towards the progressive submission of science and technology to power and money (Pestre 2003, Bonneuil and Joly, 2013). On this basis, researchers and citizens can converge towards a defense of the independence of research, as long as this independence is considered vis-à-vis the "system", in the Habermasian sense of the term.

With nanotechnologies and their controversies, it becomes necessary to consider another starting point: the process of civic politicization of nanosciences and technologies through contestation. This civic politicization manifests itself through a claim, formulated in the public space, to control, even to master the evolution of research, including academic research, in order to democratize scientific policies. This attempt at democratization has manifested itself strongly through public, associative or institutional debates, and it has revealed a marked divergence between researchers and protesters (some of whom are former researchers). However, it has not led to the exercise of civic control over nanoscience and nanotechnology.

Nevertheless, the protests have provoked significant and unforeseen changes on the side of academic research itself. These changes have resulted in the consideration of risks from the academic conception of nanoparticles. As a consequence of this consideration, the examination of the relationship between a nanoparticle and its environment, which expresses toxicity problems, paradoxically becomes a springboard for disciplinary cooperation leading to new approaches to nanos, going beyond the sole consideration of risks.

## 2. Nanoscience facing the risks assessment process

In this perspective, the emergence of a research path oriented by "safe by design" constitutes a scientific shift, given the French specificity marked by institutional separations between scientific disciplines.

We can highlight the fact that, in the face of the civic politicization of nanotechnologies, the "safe by design" approach is leading to changes in academic research on nanotechnologies. These evolutions are characterized by an innovative interdisciplinarity that is not limited to an external cooperation between disciplines around an application, but represents the spring of a transformation of the disciplines themselves, whose borders are moving. These developments also place researchers in a new relationship with industrialists, who appear to be increasingly dependent on research to market products that do not immediately fall under the challenge of consumer and environmental associations.

Despite the opening of certain programs to the financing of research on health-environment effects, the difficulties are only slowly disappearing. For example, when researchers are willing to continue a research project funded by the National Research Agency in 2006, the latter informs them of its rejection of the eco-toxicological part of the new project. However, although the absence of a sufficiently strong policy on the financing of research on risks explains the lack of available data in toxicology and ecotoxicology, the difficulties are above all scientific.

Indeed, the inadequacy and unsuitability of toxicology and ecotoxicology methodologies for nano-substances quickly becomes apparent. The traditional principle based on the idea that "the dose makes the effect" is not valid at the nano-metric scale. In particular, the problem of low doses, invalidating a common practice of overloading concentrations to obtain a toxic or eco-toxic effect and, thus, publish, is strongly posed.

At the nano-metric scale, the demonstration of effects on health or the environment can only be understood from the knowledge of the interaction mechanisms between the elements of a medium and the nanoparticles. However, the modeling of these interactions represents a major scientific advance. It allows us to go beyond, or even abandon, very old methods, but the difficulty is real insofar as researchers do not understand cellular metabolism. However, moving away from the "dose-effect" principle and theorizing the interaction mechanisms between nanoparticles and a protein or DNA, for example, opens the way to a new field of research. The assessment of risks related to "nanos" can only be done through the invention of new protocols and methodologies, which would profoundly redefine the traditional frameworks of analysis in toxicology. It is even a question of considering new researcher profiles, capable of mastering the elements of two approaches, the physics or chemistry of particles and the toxicity of the latter.

However, the fundamental fact is not directly linked to the renewal of the epistemic, methodological and experimental frameworks, which is imposed on toxicology and eco-toxicology. The history of science has revealed a number of ruptures of this kind. The most striking fact is related to the consequences of this challenge: it leads to taking into account the risks and the evaluation of health-environment effects no longer downstream from the design and production of materials and applications in the laboratory, but upstream, thus making risk a parameter in its own right in the development of nanoparticles.

## 3. Developing a "safe" approach to nanomaterials: cultural obstacles

The disciplinary divide, which reflects a very old and deep-rooted trend in science, between nanoscience (dedicated to the design and production of "nanos") on the one hand, and toxicology and eco-toxicology (dedicated to risk assessment) on the other, has doubly separated these two research fields.

Until the turn of the 2010s, these fields maintained an external relationship that only slightly compromised the practices, orientations, methodologies and theoretical frameworks of each. Although these two scientific fields coexist in certain research projects, the institutional pressure to develop inter-disciplinarily is weak. Thus, without any institutional incentive, the collaborations that will gradually take shape between these two scientific "universes" are all the more unexpected. One observation will serve as a lever.

In addition to the lack of knowledge of the interaction models between a nanoparticle and the elements that make up a medium, there is another difficulty, also specific to the nano-metric scale: the toxicological behavior of a nanoparticle varies according to its characteristics: a carbon nanotube is not identical to another carbon nanotube manufactured under conditions that are even slightly different from the first. As a result, the search for toxicity must be carried out, not at the level of a chemical species, as is traditionally the case, but at the level of a singular nanoparticle. For researchers, it is thus impossible to talk about nano-silver: on the contrary, it is necessary to deal with nano-silver, which implies introducing the physicochemical characteristics of the particles to evaluate their toxicity. Under these conditions, for research on the risks associated with "nanos" to provide convincing results, some researchers consider that it would take 50 years to know the toxicity of existing nanoparticles.

The singularity of the behavior of nanoparticles in the environment represents a challenge that can only be overcome through close collaboration between "nanos" designers and toxicologists. Knowledge of the interaction mechanisms between the environment and nanoparticles opens a new field of research, and the dependence between the two fields of research is reciprocal. This is an opportunity, particularly for physicists and chemists, to better understand the problem of nanoparticle properties. For toxicologists and eco-toxicologists, the need for precise characterization of samples requires cooperation with physicists.

This new field of research is not limited to borrowing disciplinary knowledge or combining them. It requires the construction of new frameworks of analysis, configured by researchers who have embarked on particular research, to the point, for some of them, of establishing a new discipline. Nevertheless, the scientific leap represented by these approaches does not follow a linear path, and this approach is only slowly spreading in the laboratories.

On the one hand, this leap constitutes a risk for researchers who must leave their disciplinary comfort zone to explore new avenues and broaden their skills in areas significantly removed from their core business. This is a long process, for cultural reasons. Most often, it is a slow, on-the-job learning process.

Furthermore, disciplines do not progress at the same pace in this collaborative process. Historical and cultural distinctions introduce an important gap within the material sciences themselves - i.e. between physics and chemistry - confronted with collaborations with toxicology. Physics is much more hesitant than chemistry insofar as chemists are more concerned by risks, if only because of the existence of a chemical industry, some of whose catastrophes have challenged researchers.

In addition to these difficulties, there are problems related to the institutional recognition and valorization of this new research.

## 4. Obstacles linked to the institutional organization of French scientific research

In the field of "nanos", the questioning of disciplinary boundaries is a consubstantial aspect. Since the launch of the NBIC project on the "convergence of technosciences", developed by the National Science Foundation in 2002, the prospect of increasing human capacities through the exploration of the living/non-living frontier has provided a lasting orientation for nanoscience research.

The injunction to interdisciplinarity between physics, chemistry, biology and computer science is leading to a reshaping of research programs (De Kerorguen, 2006) and tends, through the pressure of funding, to structure scientific developments in these four fields... but not without difficulty. In France, the power relations between these different scientific communities in order to control their activity (distribution of tasks, organization of working time, management of instruments, etc.) do not facilitate disciplinary rapprochement (Jouvenet, 2012). Interdisciplinarity thus presents itself as both a strategy and a problem. Thus, although the forms taken by these collaborations are variable, leading to situations of real cooperation or to what looks more like a display to obtain funding, the trend is for researchers from these four disciplines to engage in close and stable collaborations.

However, in this French landscape marked by a strong incentive to interdisciplinarity, the rapprochement between nanoscience on the one hand, and toxicology and eco-toxicology on the other, is not an institutional priority. The classic difficulties of interdisciplinarity are manifested, in this case, at several levels: recruitment and career development within disciplines, difficult acquisition of knowledge outside the discipline, lengthening publication times, and the limited number of recognized journals that value this type of interdisciplinarity and are likely to accept work "outside the field" .... Interdisciplinarity between toxicology and nanoscience of matter appears to be a new threshold to cross, but the approach is uncertain in terms of scientific production and, therefore, institutional evaluation of researchers and laboratories.

The problem appears clearly in certain circumstances, such as the financing of theses, either because the strongly interdisciplinary approach is not validated by the organizations, or because it may be impossible to find "rare birds" with a double disciplinary profile.

The expansion of collaborations between the sciences of matter and toxicology thus depends all the more on the ability of researchers to overcome, on their own, institutional barriers.

This scientific movement will have another spring and another consequence: it will lead to an unprecedented rapprochement between laboratories in nanoscience and companies, associated in a spiral, which can be considered "virtuous", of risk suppression.

## 5. Industrial practices facing necessary transformations

The impossibility of understanding the risks associated with nanoparticles in a generalized way has led researchers to establish close relationships with industrial companies. Each company adopts its own manufacturing processes and uses different nanoparticles. The evaluation of the health-environmental effects of marketed products cannot be carried out without access to nanoparticles and their characteristics, which are unique in each case, as well as to industrial processes. For example, researchers realize that the carbon nanotubes used in laboratories are not those used by industry, which invalidates their toxicity or ecotoxicity assessment work. Far from the constraints imposed by funders, forcing laboratories to move ever closer to R&D, researchers in nanoscience and toxicology are therefore voluntarily entering into partnerships with industry, at least with interested companies.

Beyond a scientific necessity, access to industrial samples also helps to overcome budgetary problems. Indeed, the cost of producing nanoparticles is such that laboratories do not have the budgetary resources to produce them in sufficient quantity while ensuring their variety (in practice, undetermined). A successful collaborative experience is the creation of a joint laboratory between an academic laboratory and that of a large industrial group. The resources allocated by the industrial company, as well as the sharing of information and skills, have catalyzed the progress of fundamental research on "nanos" risks and have allowed a broadening of research.

But research-industry collaborations can go far beyond a mutual interest that is well understood by both parties. They are likely to pave an original path in the treatment of "nanos" risks.

For industry, these collaborations have a double advantage. On the one hand, despite a persistent reluctance to reveal the composition of the products they use or market, the assurance of some confidentiality, included in the research contracts, allows them to discuss the toxicity of their products more openly with researchers. On the other hand, because the researchers place themselves in a perspective of innovation and not in a posture of control or sanction, as the administration logically does, the process enters into an approach that can be "progressive".

This dynamic therefore depends, to a large extent, on the dynamics of researchers who are called upon to go beyond their traditional role of "knowledge producer" to take on the role of stakeholder in societal issues marked by strong tensions between economic development and health-environment requirements. Of course, researchers do not necessarily interpret their approaches in the context of this role, since they are primarily responding to academic requirements. From their point of view, it is not formally a question of so-called responsible research or innovation, such as that displayed by institutions. The researchers' approach is primarily motivated by access to industrial samples and by the scientific advances thus made possible. However, the idea of shifting their practices towards safer production offers opportunities to the industrialists themselves, particularly in the face of pressure from the public and, where appropriate, from the State.

## 7. Conclusion

The social experience of nanotechnologies highlights the major difficulty encountered by institutional regulation of the risks associated with them. In the short or medium term, the regulation of nano-risks by the State via regulation or by the production of international standards cannot be the only possible way forward due to the absence of stabilized metrology, data on the toxicity of nanoparticles and commercialized "nano-like" products.

The application of the precautionary principle, even if it has been constitutionalized in France, also proves to be a poorly marked path, given the difficulty of adopting proportionate and effective measures when it comes to nanoproducts that are poorly defined. The demand for a moratorium on research has also shown its limits, notably because of the international nature of research, which does not guarantee that a halt to research in France could generate its equivalent in other countries.

The dynamics coming from the scientific sphere opens new perspectives. The emergence of an original field of research, based on the consideration of risk from the design phase, offers the possibility of proposing nanomaterials that are a priori safer, but this remains to be demonstrated. Apart from a more traditional involvement, specific to certain disciplines, in the process of understanding risks, academic research is potentially placed in a new role: that of promoting and, above all, accompanying the transformation of products.

In this context, the reconfiguration of research-industry relations is likely to complement the possible reinforcement of risk regulation if the hazard were to be eliminated at source. The research sphere is thus called upon, even involuntarily, to play a role that goes beyond its activity of producing knowledge or, at least, fundamental academic knowledge.

It remains to be seen whether, and how, this double dynamic: interdisciplinary rapprochement between nanoscience and toxicology and renewal of the relationship between research and industry, can be generalized. This generalization implies, first of all, a major evolution in research institutions, allowing building a framework for interdisciplinary practices (recruitments, careers, access to funding). It also implies an evolution of industries committing themselves, from the first stages of technological maturity, to a transformation of their practices to manufacture nanos products, a transformation that responds to the renewed requirements of product safety throughout their life cycle.

However, there is no doubt that this challenge also implies a global reflection on the social relevance of nano products, on the reasons that would lead to their development. In this perspective, research that questions, on a theoretical level, the very idea of the benefits of nanotechnologies, for example for health and the environment, must be carried out by integrating the possibility, but not the certainty, of controlling the risks upstream and, also, on a case-by-case basis.

This requires cooperation between material sciences, (eco)toxicology and social sciences, which represents a new epistemic challenge but also a normative condition for any development of nanotechnology.

## References

BECK U., (1981/1986), *La société du risque. Sur la voie d'une autre modernité,* Paris, Aubier

Bonneuil Ch. et Joly PB., (2013). *Sciences, techniques et société*, Paris, La Découverte

Cao C., Appelbaum R., Parker R., (2013). "Research is high and the market is far away": Commercialization of nanotechnology in China, *Technology in Society* 35(1), p. 55–64

Chaskiel P., (2013). « Syndicalisme et nanotechnologies. De l'espace des relations professionnelles à l'espace public des risques », *Sociologie du travail*, vol. 55, n° 4, pp. 474-494

Chateauraynaud, F. (2005). « Nanosciences et technoprophéties. Le nanomonde dans la matrice des futur », Version du 30 avril, http://halshs.archives-ouvertes.fr/docs/00/11/19/98/PDF/nanotechnos_FC.pdf

Habermas J., (1997), Droit et démocratie, Entre faits et normes, Collection NRF Essais, Gallimard

Johansson, M. & Boholm, Å. Nanoethics (2017). 11: 229. https://doi.org/10.1007/s11569-017-0297-2

Jouvenet M., (2018). « Nanosciences et nanotechnologies : une coopération modèle ? », *Terrain* [En ligne], 58 | mars 2012, mis en ligne le 01 janvier 2014, consulté le 20 septembre 2018. URL : http://journals.openedition.org/terrain/14645 ; DOI : 10.4000/terrain.14645

Kelty, Ch., (2009). "Beyond implications and applications: the story of 'Safety by design'", *NanoEthics* 3(2), p.79–96

Kerorguen Y., (2006). « Les nanotechnologies, espoir, menace ou mirage ? », Editions lignes de repères

PCast, (2014). Report to the President and Congress on the fifth assessment of the NNI, https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_fifth_nni_review_oct2014_final.pdf

Roco MC., Sims Bainbridge W. (2002). *Converging Technologies for Improving Human Performance, Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Edited by Mihail C. Roco and William Sims Bainbridge, National Science Foundation, June 2002, Arlington, Virginia

Suraud MG., (2014). « L'espace public des risques. Concertation *et* communication », *Revue française des sciences de l'information et de la communication* [En ligne], 4 | 2014, mis en ligne le 01 janvier 2014, consulté le 26 juin 2016. URL : http://rfsic.revues.org/883

Van de Poel, I. & Robaey, Z. (2017). Nanoethics, 11: 297. https://doi.org/10.1007/s11569-017-0301-x

Wang X., (2015). "Revisiting Upstream Public Engagement": from a Habermasian Perspective", *NanoEthics* April 2016, Volume 10, Issue 1, pp 63-7