Is the nano-risk a chemical risk like the others?

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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 were, for chemical risk, at the origin of the creation of the system of reparation in the OSH (occupational safety and health) which is relative to a given cultural situation in a specific space and time. The possible translation from chemical risk to nano-technological risk is discussed in the present paper. The difficult definition of what is a nano-particle is a first obstacle on this transfer. A second corresponds to the integration of numerous nano-systems into devices, leading to a more complex way to explore the cause-effect relationship used in risk mastering.

Keywords:

Health risks, nanotechnologies, risk assessment, risk mastering

Introduction

Nanotechnologies, governed by the artifact creation, register for most of the developed States as an important factor of technical progress, real grandiose form of technological utopianism. This is the expression of political and industrial powers, supported more or less by the scientists. During numerous years, the experts authority restricted democratic functioning by denying right to decide (even to judge); examples are numerous (in France, as examples, dam of Tignes in 1950s, choice of nuclear technology to produce electricity, etc.). The "ignorant" citizen has been led to accept the evolution imposed by the top in return of certain existent "advantages" from the technician society. However, recently, just like GMO's, whose advantages are far from being understood by the public opinion, the proposals of powers have been strongly restricted and are the target of large polemics.

But, in most of the recent French operations (GMOs, Nanotechnologies, nuclear waste management called CIGEO, etc), the invitation to debate was centered on "quantitative" principles of standardized explanations by a reduced benefits – risks expression, leaving the impression that everything, is under control… Every "living together in a good way" obliges all stakeholders in a minimum of understanding on what is the meaning of good, including contradictory interpretations, with the risk of a translation by the quantitative regulation of the social reports.

Nevertheless, in the main messages which they can represent in large traits, the risk aspects were illustrated by an analogy of the Carbon NanoTubes (CNT) with asbestos, and of transformations (still utopian) of the Human being. In these two cases, nature and largeness of effects is not today available (even if studies of toxicology are under development). This reinforces a general feeling of insecurity and of loss of trust in the State. Nowadays, the state cannot then take easily refuge in an ideology of general interest which would bring back the society to docility and to unification.

The definition of risks and their mastering should be a means to make feel this ideology not as oppression, but on the contrary as a stabilizing element, an honest, fair and without flaws relation… Indeed, fighting on quantitative indicators is justifying and validating the reductionist notion of quantitative landmark to judge. We would not have any more to be concerned about ethical evaluation (respectability, freedom, integrity, respect for the person, quality of private life, justice, equity), just of possible "compensations" (with an assurance sense) to take into account effects on health. If this purpose is attained, the society will be able to think that it will be possible to conjugate innovation, job, common goods and economic development.

This consideration indeed introduces the incorporation of this problem inside the paradigm of the mastering of risks leaning on known relationships between causes and effects for which the definition of what constitutes the cause is essential since it is linked to the recognition of causative link between cause and its result (as it takes place in the occupational diseases tables). It is therefore a juridical necessity to define a dangerous element different from a massive material, which is not obvious in terms of research of cause-effect relationship (when we know that less than 5 %-10 % of hazards linked to industrially chemical substances are probably known).

Chemical risk and recognition of occupational diseases

In 1830s, more than two thirds of the young French workers were declared unfit for military service, but it was necessary to wait till 1874 for the birth of an official regulation of hygiene and safety at work (which nevertheless too much did not change the lesson of things) (1). From a historical point of view, the health at work begins in the years around 1840. The French Academy of Sciences, in agreement with the army, reported alarming picture of the physical and moral state of the working population. This state of art justifies an intervention of the State to preserve the wage-earning population, then in constant increase due to industrial development, and to assure the future of the society. The occupational physicians (or what serves as it) made of occupational diseases a collective trial, but with mixed results, since the first picture concerning occupational disease lead appeared only in 1919 (2-4). The French State developed several laws, in order to subtract the weakest populations from risk to protect them: In 1893 is issued the first law which concerns all the workers. This law prescribes rules that should allow (in principle) to control risk. This approach of mastering of risk supplements the initial approach. For instance, 11 decrees of July 11th, 1913 prescribe rules applicable to certain activities (laundry, textile industry) or at certain specific risks (lead, electricity, compressed air). The principle of statement and occupational tables were born (5).

Today, a disease is said occupational if it is the direct consequence of the exposure of a worker at a known physical, chemical or biological risk. It can also result from conditions in which the worker practices and if it appears in one of the table of the general or agrarian regime of French national health and pensions organization (National Social Security System) published in the official Journals of the French Republic. To make an easier understanding, every occupational illness table is accompanied with a medico-technical comment, written by experts (6). The tables of occupational diseases are created and modified after opinion of the upper council of the prevention of professional risks (7). Any illness indicated in a table of occupational diseases and contracted in conditions mentioned in this table "Article L.461-1" of the Code of French National Social Security organization is presumed of professional origin. Occupational diseases result from chronic exposures to physical agents (noise, vibrations, ionizing radiations, etc.), to chemical agents (toxic, carcinogenic, mutagenic, repro-toxic, etc.) or to microbes an agents (viruses, microbes, protozoa, moistures, etc.).

So this database allows answering to the following questions:

• Is the exercised activity likely to lead to an occupational disease?
• Can a given illness have a professional element?
• What measurements must be set up to prevent a given illness?

By taking the example of lead, one of the most ancient toxins of which the effect on the workers was the object of recognition in terms of occupational diseases, INRS (6) provides several compositions containing some lead which today can be the object of such recognition:

• 10099-74-8 (lead nitrate)
• 1309-60-0 (lead dioxide)
• 1314-41-6 (lead tetra-oxide; red lead
• 1314-87-0 (lead sulfide)
• 1317-36-8 (lead monoxide; lead oxide)
• 598-63-0 (lead carbonate)
• 7439-92-1 (lead metal)
• 7758-95-4 (lead chloride)

•7758-97-6 (lead chromate)

•Alloy lead-arsenic

•Alloy tin-lead

•Composed with lead

•Arsenical ore of lead

This result obviously that INRS take into account not only the presence of a chemical element, but also its specific nature. According to Camipinfo (8) it is possible to find in Tables relations between exposure and effects in the case of this metal and its compounds. In this respect, the example of a work activity allows to take better into account the possible effects and specific ways of prevention.

Nevertheless, these occupational diseases tables do not appear of course from a "cold" knowledge translated into occupational diseases which would be of professional origins for different reasons:

•Possibilities of the existence of possible confusion factors (for instance, it has been claimed for a long time that the miner silicosis could be linked to tuberculosis);

•Obligation in industrial toxicology activities to work on the exposure of animals on products/chemicals perfectly characterized to avoid effects linked to impurity and come back into an obvious, and as one might say, exclusive link between cause and effect;

•Difficulty to translate the results obtained with specific animals to reflect the human being;

•When risks are measured over long periods, it is possible to realize works of epidemiology on the effect of industrial products (none totally pure); but these effects are credible only if they are associated with a sufficient cohort;

•The necessity of a social pressure for a possible evolution of occupational diseases tables. For example, the obviousness agreement between State, Employers and Labor unions restricted the real protection of the coal miners because it was difficult to forbid, after the second world war, exposure in the "coal" dusts of a hardly substitutable strategically material at an allowable cost…

•The possibility to try to lateralize problems. As Héry (9) writes, "it will be the genius of CPA (asbestos permanent committee) to make the main actors believe that it is possible to control situation in France, when other developed countries were obliged to ban the "controlled use" of this mineral"… In order to have a large view, it is necessary to be interested in what must be seen and not what it is necessary to see, by focusing attention on certain salient facts or on certain actors (10).

It is what allows Rosental (11) to write: "History exhumes the foundations of the dynamic contemporaries by reconstructing their progressive installation in the course of time and by assessing their relative permanence. The lawful and institutional dispositions, but also, in a less immediate way, the identification of social force involved in collective problem, as well as their respective influence dominate here. The historical approach is all the more explicative as these pillars […] keep their positions on a long term basis".

To illustrate the "opportunistic" aspect of the establishment of a specific table, it is possible to analyze the creation of the table 25 (professional silicosis) further too strong pressures by the CGT-FRENCH TRADE UNION who put pressure on an interim government constituted by the General de Gaulle. This one and the three communist ministers signed decision, real political act in a country where coal represented about 80-90 % of energy resources from France (12). In comparison, it has been necessary to wait for 1963 so that Belgium, under the pressure of the miners of Italian origin, really acknowledges silicosis as occupational disease.

So, the modern acceptation of prevention fluctuates between utilitarian calculation to a generous donation, and the research of the interest to the requirement of disinterestedness… "There is a possible confusion between requirements of the heart and of the reason, without being able to discover which one carry the mask of the other, allowing probably to eclipse divergent strategies inside the field of the prevention of professional risks" (13). However, since 2006, the producer has to assure the harmlessness of a chemical (cf. regulations (EC) N. 1907/2006 of the European Parliament and the Council of December 18th, 2006 concerning recording, evaluation and approval of chemical substances, as well as applicable restrictions in these substances (REACH). Similarly, the "unique" document revised in principle yearly by firms must assure the workers of good functioning in terms of hygiene and security at work in

firms. It applies to all forms of risks (and therefore, we will see it later, in nano-particles).
Figure 1 gathers most of the elements discussed in this part dedicated to social agreement on finally accepted risks (at work) as much as defines, in what and where, chemical risks can be present and, in a accounting way, aspects financial compensations and protection of the operators (14).

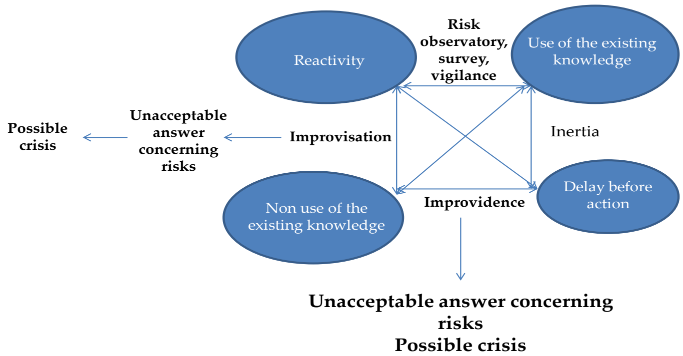

Figure 1. Semiotics square explaining the emergence of crises and the necessity to react "on time"
In order to propose a summary of chemical risk and the associated occupational social insurance, we have to admit that:

- There is a relation, as causative as possible, between a cause and an effect;
- Effects are questioned so that resolutions of prevention have to be founded;
- In order to get the system flexible and changing, a robust demonstration of the effects is necessary: epidemiology (even popular epidemiology); experimental toxicology, etc. In this last domain, approach requires to work on pure products or perfectly characterized materials. The difficult question is the translation from studies realized on specific animals to the accepted definition of hazard for the workers.
- Importance of the effects (nature, number, amplitude, cost for the Society at work, etc.) should be, or at least estimated;
- The social pressure of the world of work (trade unions as an example) is an element of historical pattern of the implement of recognition of occupational diseases.

The situation of environmental risks is more complex because it is not directly linked to a financial compensation aspect. Citizen pressure translated (sometimes) by the rejection of a technology, even if there are ways of relation between polluting firms and populations (public debates, prevention plans, etc.).

And the nano?

"A nano-material is a material having particular properties because of its nano-metric structure. It habitually comes from nanotechnology" (15). In these tautological definitions, it is necessary to search that linked to nanotechnology: it is "a generic term which represents applications in numerous scientific domains but cover generally research on principles and properties existing in the nano-metric scale, that is to say at the level of atoms and at molecules ". But it is not molecular or ionic chemistry! "The objective of nanotechnologies consists in producing objects or materials (a dimension of which at least is) smaller than 100 nanometers. These nano-materials are composed of nano-particles which, contrary to the very fine particles of origin natural or coming from combustion processes, are intentionally produced. Nanomaterials can be metals, ceramics, carbons, polymers or else silicates which are of the interest for their specific characteristics in comparison with the same materials in the macroscopic scale. The mastering of these new physicochemical properties opens so a huge field of researches integrated under the "nano-sciences" label (16). The applicative field of these materials (17-19) is particularly broad.

According to Industrie.gouv (20), "nano-sciences refer to the study of phenomena observed in structures, systems-objects size of which is some nanometers and among which the physical, chemical or even biological properties ensue specifically from this nano-metric size. Nanotechnologies deal as well the manipulation of atoms and molecules (which the typical dimension is the nanometer), the miniaturization of structures and studying new processes, phenomena and specific techniques in the nano-metric scale. They open totally new ways of research and their development often requires multidisciplinary competences. Considered to be the basic tools of innovation of tomorrow, their applications already have impact in the life of each person and should contribute to assertion or to growth of activity in the most part of the manufacturing areas".

"The world of nano-sciences and nanotechnologies - the "nano-world" – corresponds to the objects of nano-metric size among which certain phenomena and effects are unforeseen. These peculiarities open them broad spectra of applications and even if some applications are already around us, their potential of development is considerable" (21).

For the nano group of the NATIONAL CENTRE FOR SCIENTIFIC RESEARCH (19); "Nano-sciences and nanotechnologies have as objectives creation, mastering and use of objects or objects assemblies of extremely reduced size, being near the nanometer. In these dimensions, close to the nuclear or molecular distances, material acquires new properties allowing very numerous applications. Nano-sciences and nanotechnologies are in constant progression, some them considering even as an important key of the economic development of the 21th century". It is the conjugation of both approaches of nano-manufacturing, "top-down" and "bottom-up", which allows, as we shall see it later, the constant evolution of the scientific and technologic domain and should prove to be promising for the future.

However, nano-sciences and nanotechnologies are not the result of a violent break. They result from a natural evolution of several scientific disciplines stretching over several decades. Among the important elements of this strong evolution they can name: progress in sciences and engineering of surfaces, colloids, interfaces and aggregates, advanced research in physico-chemistry of materials and objects of nano-metric size, major breakthroughs in instrumentation, possibility of manipulating atoms, tendency supported of miniaturization in micro- and now nano-electronics, manufacturing and characterization of micro- and nano-systems, growing association with biology (bio-inspired systems), and advances in theoretical and numerical approaches.

Nano risk perception

The same risk can be received differently by several individuals (22). Numerous factors can have an influence on the perception of a risk. According to Kouabenan *et al* (23), this perception can vary according to risk itself, characteristics of the person and its personal history, or the culture of social or organizational body. Numerous studies were conducted to evaluate the perception of the risk linked to the development of nanotechnologies. Most of these studies show that, in spite of its insufficient knowledge of the public on nanotechnologies and their applications, people receive nanotechnologies as promising and imagine that benefits will easily exceed potential risks (24).

However, the food area remains a sensitive point. Indeed, these studies show that the public is more reticent and more suspicious for the things which touch directly feeding and all that can be ingested (24, 25). So the public will tend to accept more easily products touching the food in the packaging rather than applications where nano-products are directly added into the food, even if contacts are possible as it can take place with the silver nano-particles [25]. Besides, it seems that the public mistrust is rather of the government and industry, especially when it is a matter of the interest of the public or the management of risk. In a recent study, Marcellis, Warin and Peignier (26) showed that only 2% of the natives of Quebec have an opinion absolutely in opposition of the development of nanotechnologies and 13% are preoccupied by risks they would bring. But a 32.6% majority is without any opinion on the subject. As a consequence, nanotechnologies are not along the worrying subjects of the population of Quebec (27).

However, means of communication chosen to share the information relating to these emergent technologies have an influence on judgment and opinion established by the natives of Quebec. So these studies show that the public expects to be consulted on the development of these new technologies, informed on the risk at which he/she is displayed and to participate in either way, in the management of this risk. The communication aspect is therefore an important tool and must be often used to improve the social approval linked to nanotechnologies (27). A French study, less deepened, accomplished in Nancy as part of a studying work lead to the same conclusion. In the particular case of nano-health and/or nano-medicine, the repondants are besides on the whole unanimous to test new technologies in case of very serious diseases (28, 29).

Is a nano-definition useful?

In a recent work, the public debate on the "nano" topic was analyzed and lead to a very weak request on behalf of organizations having produced "actors' notebook" on the notion or concept of nano-definition (30). And, they will have definitely noted it, like in the case of chemical risk, the definition is a precondition in any attempt of occupational risk prevention, inside the paradigm of the mastering of risks leaning on relations causes-effects known for which the definition of what constitutes the origin of the risk is essential since it is linked to

the recognition of causative link between the cause and its result (as it takes place in the tables of occupational diseases).
Then, as in the case of chemical risk, how is it possible to characterize nano risk?

- Identification of a real dangerous situation for the Human and the environment;
- Characterization of this dangerous situation (by epidemiology, experimental toxicology, etc.);
- Analysis of different real and potential impacts;
- Responsible management of the risks;
- Public perception of nano-hazards and possible negative amplification by absence of a (good) communication;
- Regulation and prevention of professional and environmental risks.

One of the obstacles which explain partly the lack of knowledge in industrial hygiene is that the actual tools of evaluation of the methods used for workers exposure are badly adapted to application in the case of nano-particles in working conditions (measures of forms, size, surface effects, agglomerations, time evolution of the chemical properties, etc), while some available data suggest that exposure can be substantial during indoor manipulation. Secondly, the specialists do not agree on the relevance of existent regulation (actual debate in ISO on the definition of nano-particles). It is difficult to decide on the mastering of risks as long as more definite data on the potential effects of nanotechnologies will not be available. By waiting for a more consistent progress of research and regulation, better adapted to the peculiarities of nanotechnologies, it seems reasonable that the precautionary principle guides actions to be undertaken to protect health and safety of the workers, as well as of environment (31). Let us say that the precautionary principle is linked in France to "Barnier" Law N° 02-02-1995 – articles L.200-1 of country code and L.110-1 of the code of environment summed up below: "The precautionary principle according to which the absence of certainties considering scientific and technical knowledge of instant, should not postpone the adoption of real and made proportional measures aiming at avoiding a risk of serious and irreversible damage in environment at an economically tolerable cost".
Considering the nature of REACH, debates on the integration of nano limit principally themselves to identify if we are dealing with something new and

therefore to demand particular safety measures, or not, and if their volumes of production impose to include them in legislation, or not. In view of the cause of concern regarding the toxicity of nano-materials and in their potential harmful effects they can have on the Human and/or on environment, we could hope that decisions will be made and treated by regulation in the next years.
However it is necessary to look at the reality. In the absence of social pressure, and real effects showing an indisputable real risk of nano-particles on the Human, numerous questions remain opened:

- Is it possible to measure the effects of nano-particles in environment and in human health: effects of size, time evolution of chemistry of surfaces, presence of secondary elements (impurities), etc. (cf. chemical risk);
- How applying "intelligently" the precautionary principle to the domain of nanotechnologies?
- How allowing, the public to achieve information without formatting?
- Can we use the existent regulation frame (for instance the "unique" document, annually in charge of the enterprise directorates) to manage risks induced by nano-particles (and in a more general way by nanotechnologies)? Must we define a new one, based on which foundations?
- How to make sure that the regulation frame would be comprehensible, efficient, acknowledged on the scale of the globe, transparent and, if necessary, progressive?

Nanotechnologies are probably going to produce robots of tomorrow. But unlimited combinatory that they constitute is large enough, to make obsolete the precautionary principle. Every molecular layer, every association of atoms, every added property, and every combination of elements can introduce a particular and specific risk. Only the evaluation of risks at the level of end products can have a sense, at the same time as an analysis of risks at the end of life (recycling for instance)… The table 1 illustrates a supplementary difficulty in regulation approach linked to the rapid enlargement of the field of intervention of nanotechnologies. Not only, it is difficult to characterize them in a natural environment (especially in the presence of "natural" nano-particles, which have not anthropogenic origin), but their applications are becoming so numerous; they will avoid in a obvious way the elementary notion of chemical risk led by nano-particles. The room to maneuver of the decision makers (State and Industry) becomes very small and it is very difficult to regulate the use of nano-particles in a very complex system, hardly globalized. We can probably explore some "safe by design" technologies (but will they have taken into account of the future of nano in possible recycling, return of existent particles in the atmosphere during the wear of materials, etc.)? Then let us add that if regulation is a hardly approachable wish, sustainable innovation, or even social, implicating nano-systems, risk being just as much (32).

System type	Generation	Definition	Use	Risks
Nano-materials and passives nanostructures	First generation, already available	Nanomaterials are able to modify the properties of existing materials	- Solar screens - Textiles - Cosmetics - Painting - Sport devices	- Toxicity for Human and/or environment - Social and economical impacts, - Social repartition of the ratio benefit/risks - Responsibility intellectual propriety - Consumer risks - Risks at work
Actives nanomaterials	Second generation, under testing	Smart and intelligent nano-systems	- Drug administration - Genetically produced pesticides	- Un-stability and un-predictable behaviors of nanostructures - Enhanced risks for Human and/or environment - Strong impact on ecosystems
Integrated nanomaterials	Generation after 2012	Complex integration of nanostructures leading to new properties	- Artificial organs for medical use - Synthetic biology - Human enhancement	- Unexpected and dangerous behaviors of genetically modified organisms - Global consequential effect
Heterogeneous	Forth generation	Advanced handling for the	- Nano-sized genetic	- Possible disasters induced by non expected

molecula r systems	after 2015	complex creation of molecular structures with complex properties	therapies –- Supra-molecular systems	changes for the planet - Private life and freedom

Table 1. Possible evolution of the different nanotechnologies and the associated potential risks

A provisional conclusion

Ulrick Beck (33) reminds us that "it is not any more the largeness of risk that changes but its "Scientification" which does not any more allow off-loading its responsibilities on Nature". The researcher cannot stay any more in his cozy silo and must be interested in the World by coming back certainly in a modest manner to a less modular, less mono-disciplinary production.

We must participate to the coordination of productions with the aim of a operatory effectiveness interesting the society, and throughout open in a culture less formatted by the reductionism of a linear thought. This necessary responsibility (but probably deficient) is one of the means to get closer to an anxious society, badly formed, badly informed with changeable wishes… It is in the alder of this reconciliation that it will perhaps be possible to avoid untimely and unpredictable controls, but it imposes a finally new responsible character in its expression and in the will of the State (34, 35).

In any case, this radical change assumes a real societal whish if we want to make the nano-research a socially useful tool inscribes in length in the world which explores new paradigms such as risks and vulnerabilities. And, as suggested A. Einstein (36): "No problem can be resolved without changing the mind which procreated it". This strong agreement risk of being a rhetorical device using lazy and easy course in imprecations sloganized which consist merely to a communication for maintaining a brand image. We said it; it's as if it was made! Just look at the reduction of the production of carbon dioxide in the environment which is a founded wish. In the absence of will, which is probable, it will be unfortunately possible to accomplish happily useful disciplinary research works (on nano…). Does not the case causative and lighting new technologies supported by all research agencies risk to eclipse essentials this re-visit of the role of research on risks in the world which avoids more and more wishes of the Humans?

References

1. Boisselier J. Un demi-siècle de prévention; l'OPPBTP 1947-2002, OPPBTP Ed, Boulogne-Billancourt, 2002.
2. Bonneff L, Bonneff M. Les métiers qui tuent; enquêtes auprès des syndicats ouvriers sur les maladies professionnelles, Bibliographie Sociale Ed, Paris, 1905.
3. Devinck JC. La création de la médecine du travail en France 1914-1946, UNSA Education Ed, Paris, 2002.
4. Rebérioux M. Mouvement syndical et santé, France 1880-1914. Prévenir 1989; 18: 15-30.
5. INRS. (2014). Repères historiques; plus d'un siècle d'évolution. Available from: http://www.inrs.fr/accueil/inrs/panorama-prevention/historique.html
6. INRS. (2014). Tableaux de maladies professionnelles; guide d'accès et commentaires. Available from: http://www.inrs-mp.fr/mp/cgi-bin/mppage.pl
7. Atousanté.com. (2014). Liste des tableaux de maladies professionnelles. Available from: http://www.atousante.com/maladies-professionnelles/tableaux-maladies-professionnelles/
8. Camipinfo. (2014). La fabrication de vitraux ; Historique et prévention des risques d'un artisanat ancestral. Available from: http://www.camip.info/Rappel-reglementaire.html
9. Héry M. Des recettes pour empêcher un risque d'émerger: le cas de l'amiante, in: L'émergence des risques–Avis d'experts, EDP Sciences Ed, Paris, 2008.
10. Voirol O. Visibilité/invisibilité. Lavoisier Ed, Paris, 2005.
11. Rosental PA. La tragédie de l'amiante a-t-elle modifié le régime de reconnaissance des maladies professionnelles ? Fondements historiques des perspectives d'évolution contemporaines, in: L'émergence des risques–Avis d'experts, EDP Sciences Ed, Paris, 2008.
12. Amoudru C. Pneumoconioses; l'exemple des houillières du Nord-Pas-de-Calais, in: L'émergence des risques–Avis d'experts, EDP Sciences Ed, Paris, 2008.
13. André JC. Risques professionnels ; vers les limites du modèle in: L'émergence des risques – Avis d'experts, EDP Sciences Ed, Paris, 2008.

14. Laroche H, Boudes T. La production d'intelligibilité dans les rapports officiels: le cas de la canicule. Sociétal 2006; 53: 38-43.
15. Techno-science.net. (2013). Nanomatériaux. Available from: http://www.techno-science.net/?onglet=glossaire&definition=4614
16. Actu-environnement. (2013). Nanotechnologie. Available from: http://www.actu-environnement.com/ae/dictionnaire_environnement/definition/nanomateriaux.php4
17. Tsuzulki T. Commercial and production of inorganic nanparticles. Int. J. Nanotechnology 2009; 6: 5-6.
18. Lisenky G. (2012). Nanotechnology applications. Available from: http://www.youtube.com/watch?v=43-Pb6uL1cE
19. CNRS. (2012). Stratégie interdisciplinaire du CNRS en nanosciences et nanotechnologies. Available from: http://www.cnrs.fr/mi/spip.php?article77&lang=fr
20. Industrie.gouv. (2013). Nanosciences. Available from: http://www.industrie.gouv.fr/enjeux/definition.html
21. CES. Les nanotechnologies. La documentation française Ed, Paris, 2008.
22. Meur-Férec C. (2006). De la dynamique naturelle à la gestion intégrée de l'espace littoral: un itinéraire de géographe. Available from: https://halshs.archives-ouvertes.fr/tel-00167784/document
23. Kouabenan DR, Cadet B, Hermand D, Muñoz-Sastre MTM. Psychologie du risque: Identifier, évaluer, prévenir. De Boeck Ed, Bruxelles, 2006.
24. Zimmer R, Herel R, Böl G. (2008). Public Perceptions about Nanotechnology - Representative survey and basic morphological-psychological study. Available from: http://publications.polymtl.ca/1044/1/2012_Garat%C3%89ric.pdf
25. Grobe A, Renn O, Jaeger A. (2008). Risk Governance of Nanotechnology Applications in Food and Cosmetics. Available from: http://www. irgc.org/IMG/pdf/IRGC_Report_FINAL_For_Web.pdf
26. De Marcellis-Warin N, Peignier I. (2012) Perception des risques au Québec – Baromètre CIRANO 2012. Available from: https://ideas.repec.org/b/cir/cirmon/2012mo-02.html
27. Garat E. (2013) Enquête exploratoire sur les avantages et les risques des partenariats des entreprises développant ou utilisant des nanotechnologies au

Québec. Available from:
http://publications.polymtl.ca/1044/1/2012_Garat%C3%89ric.pdf
28. Cormick C. Why do we need to know what the public thinks about nanotechnology ? Nanoethics 2009; 3: 167-173.
29. Bieberstein A, Blanchemanche S, Marette S, et al. Des consommateurs entre indifférence et méfiance: Comportements français et allemands face à une possible introduction des nanotechnologies dans le secteur agro-alimentaire. INRA 2011 ; 1: 1-4.
30. André JC. Nano-définition, pour qui? Pour quoi?, Toulouse, 2014.
31. CEST. Avis: éthique et nanotechnologies ; se donner les moyens d'agir, Gouvernement du Québec Ed., Québec, 2006.
32. Ferdigo D, Senjen R. Projet nanocap : les nanotechnologies au XXI^{ème} siècle in :Approches politiques relatives à la gouvernance en matière d'innovation ; le cas des nanotechnologies, European Environment Bureau Ed, Bruxelles, 2010.
33. Beck U. La société du risque – Sur la voie d'une autre modernité, Champs Ed, Paris, 2003.
34. André JC. Towards a Socially Responsible Research (SRR) charter in Engineering Sciences at CNRS level. Int. J. Techno-ethics 2013; 4: 39-51.
35. Glerup C, Horst M. Mapping 'social responsibility' in science . J. Responsible Innov. 2014; 1: 31-50.
36. Einstein A. Ecrits politiques d'A, Einstein, Seuil Ed, Paris, 1991.