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Nanotechnology Stewardship: Executive Report

Canadian Stewardship Practices for Environmental Nanotechnology

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Executive report¹

Nanotechnology is often referred to as the next industrial revolution and a number of experts, researchers, engineers, social scientists and policy makers consider that nanotechnology will make drastic changes to many aspects of society. Nanotechnology has made it possible to manufacture new materials that have hitherto not existed. This enabling technology is helping create a wide range of potentially exciting and innovative applications for the environment and other sectors such as medicine, electronics, communications, etc. Unfortunately, it also presents potential threats and risks for health and the environment. For instance, some nanoparticles could be toxic. Up to now, nanotechnology has evaded social, political and regulatory scrutiny, and the risks from nanoparticles in the workplace and in commercial products are unknown or uncertain. This is a cause for concern and has opened the door to public debate.

In this context, Environment Canada has articulated the need for improved understanding of the field of nanotechnology in order to shape its development in an environmentally sustainable and timely manner. Science-Metrix was selected to undertake a study of the environmental dimensions of nanotechnology. The study examines current research in nanotechnology related to environmental applications. The analysis includes research activities focusing on nanotechnology applications that will benefit the environment, as well as research that may present environmental risks and potential threats. The study also includes a comprehensive review of strategies and policies developed by the US, European and Asian countries to identify and reconcile stewardship issues associated with the development of nanotechnologies. Finally, based on the results of the study, recommendations are made to guide Environment Canada in targeting environmental applications, maximizing benefits, and minimizing the potentially negative impacts generated by nanotechnology development, thus establishing the foundations for best stewardship practices.

The present study is based on the definition of stewardship proposed by Environment Canada, which sees it as the act of entrusting the careful and responsible management of the environment and natural resources for the benefit of the general community (EC 2005). Science-Metrix has scrutinized more than 500 documents and used the information gleaned from approximately 200 of them to guarantee the soundness of this study. This in-depth review of the literature shows that without doubt stewardship practices linked to the environmental dimensions of nanotechnology are fairly rare thus offering an opportunity for Canada to adopt a pioneering position on the international scene. However, the use of documentation and the absence of actual practical observation produce important challenges in relation to the objectives of the study: it makes it more difficult to deal with negative results, as it is possible that direct observation would have produced a different result. This is why we conducted such an in-depth and detailed review. Science-Metrix was obliged to widen the perspective beyond what was considered to be the potential impact of

¹ A complete version of this report can be obtained from Dr. Terry McIntyre (Terry.McIntyre@ec.gc.ca) and from Science-Metrix' web site (www.science-metrix.com).

nanotechnologies on the environment, to include activities related to stewardship in environmental nanotechnology.

This report considers a wide range of initiatives, strategies and policies that refer to various aspects of nanotechnology (e.g. social, ethical, technical, etc.), which may seem somewhat remote from an environmental perspective per se, and which at first glance might seem to be outside the scope of the present study (this applies particularly to Section 3). However, each of these initiatives was quite deliberately selected either on the basis of their representation of a model, or for the elements they contained which Science Metrix considered should be examined and adapted to establish efficient stewardship practices targeting the environmental dimensions of nanotechnology.

This study examines two types of research on nanotechnology that have environmental implications: 1) research culminating in a potential benefit for the environment and; 2) research on the potential risks of nanotechnology for the environment.

Current research on nanotechnology presenting potential benefits for the environment

In terms of potential benefits, considerable efforts have been expended on creating a new generation of sensors with enhanced capabilities to monitor pathogen and pollutant presence in the environment. Engineered nanoparticles such as Au, Pt, CdS, TiO₂, quantum dots and nanocrystals (e.g. CdSe-ZnS), as well as nanostructures such as carbon nanotubes and porous silicon are among the most promising materials for creating nanosensors for environmental applications. Nanoprobes based on semiconducting nanowires, such as boron-doped silicon nanowires, were also reportedly able to achieve highly sensitive, label-free, and real-time detection of a wide range of chemical and biological species (Cui *et al.* 2001; Cullum *et al.* 2000; Tuan 2002). The combination of electronics and nanotechnologies to develop sensors is the focus of a great deal of research, especially for nano-electromechanical systems (NEMS). In addition, lab-on-a-chip and microarray approaches were studied with the goal of developing sensor prototypes, and examples were found in the literature of where these technologies had been combined with nanoparticles for use as nanoprobes for sensing applications.

Many scientists and researchers have shown that engineered nanoparticles such as TiO₂ and ZnO, carbon nanotube, metallic nanoparticles (e.g. iron, nickel etc.), magnetic nanoparticles and Amphiphilic polyurethane nanoparticles could be useful for remediation and treatment of contaminated water, soil or air. Interestingly, ZnO seems to offer the ability to simultaneously sense and destroy toxic chemicals (Kamat, Huehn and Nicolaescu 2002).

Utilization of nanotechnology for environmental applications also involves green technologies aimed at eliminating or decreasing harmful emissions and waste from industrial processes, and includes the development of clean energy sources such as solar energy and fuel cells improved by nanotechnology. Carbon nanotubes could allow the creation of stronger and lighter products using fewer raw materials, thereby conserving natural resources. In addition, energy requirements for these products will decrease. For instance, stronger cars, planes and other vehicles with a fraction of the weight of current models could be produced and would require less fuel, thus reducing energy consumption. Different research groups have also proposed that carbon nanotubes could be filled

with hydrogen and used as energy cells for automotive application, offering the potential to reduce atmospheric emissions (Cheng 2001).

CdSe nanoparticles have been shown to produce more efficient and cheaper solar cells. In addition, nanoparticles such as ceria are expected to improve fuel economy by reducing the degradation of fuel consumption over time (Oxonica 2003). Research efforts have been undertaken on the potential of nanoparticles for recycling or replacing toxic and harmful compounds. For instance, it has been proposed that nickel nanoparticles could efficiently recycle the CO₂ in methane to produce energy; silica nanoparticles could be used to replace toxic elements such as cadmium or chromium; sulphuric acid could be recycled from waste water in zinc ferrite powder, which is used as a component in several different applications. Other nanoparticles could enable the creation of nanocatalysts with enhanced capabilities, which are more environmentally friendly products (Lopez *et al.* 1998);(Hashimoto *et al.* 2001);(NRC 2005);(Royal Society 2004). Engineered nanoparticles and tools based on nanotechnology offer an affordable and effective approach to detecting, removing and preventing the diffusion of harmful substances in the environment.

Current research on the potential risks of nanotechnology on the environment

Scientists have recently identified several important issues related to the safety of engineered nanoparticles and attention has been focused on the potential threat to the environment and health that they present. In particular, it has been observed that high surface reactivity and very small size could help nanoparticles circumvent the immune defences of living organisms.

It has been reported that nanoparticles such as carbon black and titanium dioxide, which are used increasingly in industrial processes, and are contributing greatly to air pollution, induce inflammation and epithelial injuries, and are retained in the lungs producing dose accumulation (Moghimi and Hunter 2001; Renwick *et al.* 2004). Furthermore, titanium dioxide nanoparticles appear to produce free radicals and DNA damage in skin cells, increasing the probability of cancer developing (Dunford *et al.* 1997; McHugh and Knowland 1997). Researchers from the Center for Biological and Environmental Nanotechnology (CBEN) have reported that engineered nanoparticles accumulate in the organs of laboratory animals and are taken up by the cells (Brown 2002). The toxicity of carbon nanotubes was studied by these scientists. Evidence from this research suggests that nanoparticles induce oxidative stress on human keratinocytes, are highly toxic to rat lungs and generate free radicals and oxidative damage to macrophage and defensive cells (Shvedova *et al.* 2003);(Hogan 2003); (Lam *et al.* 2004); (Renwick *et al.* 2004; Renwick, Donaldson and Clouter 2001). Moreover, carbon nanotubes aggregate in the air and form nanocrystals, especially out of doors, with a higher incidence than do diesel particles.

The nanocrystal form of carbon particles has the potential to be more harmful to living organisms than non-aggregated forms and could be generated by combustion sources such as gas cooking stoves, industrial gas combustion and a variety of domestic heating sources (Murr *et al.* 2004a; Murr *et al.* 2004b). Also, experimental evidence indicates that unprocessed carbon nanotubes can form aerosols during handling, or with a degree of agitation (Maynard *et al.* 2004). Although more research is required, it can be assumed that there is a tangible health risk associated with the manipulation of carbon nanotubes. Moreover, carbon nanoparticles such as fullerene (buckyballs),

which is being produced in large quantities in the US, have been shown to induce glutathione depletion and oxidative damage in the brains of exposed fish (largemouth bass), causing changes in gene functions. There is also evidence to suggest that fullerene can travel through the soil and that earthworms could easily absorb buckyballs, possibly allowing this pollutant to move up the food-chain (Brumfiel 2003; Halford 2004; Oberdorster 2004). Finally, it has been shown that inhaled nanoparticles have the capacity to circumvent the blood-brain barrier in rats and to translocate in the central nervous system, suggesting that nanoparticles could travel along nerves (Oberdorster *et al.* 2004); other studies have reported that gold nanoparticles may be transferred from mother to foetus (Wootliff 2004).

Research efforts have also been dedicated to studying the potential risks presented by natural nanoparticles. It is important to set these concerns in context: combustion is probably the most important source of natural nanoparticles in the environment, and humans have always suffered exposure to some types of nanoparticles from forest fires and atmospheric photochemistry. However, engineered nanoparticles released in the environment may present greater threats to health than natural nanoparticles because they are new materials and, therefore, the defence mechanisms in organisms, including humans, may be absent or inadequate to counter them. On the other hand, with appropriate measures, it is possible to control the emission of engineered nanoparticles and to minimize their release into the environment, a situation that contrasts with the release of natural nanoparticles – which is spontaneous.

Industrial combustion and diesel combustion from vehicles represent major sources of non-engineered nanoparticle emission. The mass of exhaust particles has been significantly reduced in recent years, but effective removal of nanoscale particles from vehicle exhaust via catalytic materials and filters such as particulate traps represents a real challenge. The formation of nanoparticles with a diameter below 50 nm in diesel exhaust during dilution processes has been reported in several studies (Vaaraslahti *et al.* 2004). Considering the numbers of motor vehicles of all kinds, and of industrial combustion from factories and processing facilities, it is crucial that efficient methods should be rapidly developed to detect nanoparticles produced from these sources and to create tools to eliminate or minimize these emissions into the environment.

Important research issues

Over the next decade, research efforts in environmental nanotechnology should be oriented toward crucial issues, such as producing a more precise picture of the impact of new nanomaterials, including engineered and natural nanoparticles, on each level of the food chain and on ecosystems, and advancing knowledge of their effects on various types of organisms, by collecting data on exposure levels, characterizing dose-response and performing a wide range of toxicological and ecotoxicological tests. Other important avenues requiring further research are: determining the persistence levels of nanoparticles in the environment; evaluating the production, use and fate of nanomaterials through life-cycle analysis; identifying nanomaterials' release and transport mechanisms in the environment to living organisms; and considering key parameters such as biodegradability and bioaccumulation of nanoparticles in organisms. It is also important to evaluate whether and how current standards and treatment methods are effective in detecting and removing

nanoparticles in the environment. Research should be undertaken to develop tools to more efficiently detect and measure levels of nanoparticles in the environment and to produce effective ways of eliminating or decreasing the harmful effects of nanoparticles. In addition, efforts should be deployed to establish new standards and risk assessment methods for nanoparticles, and to develop appropriate procedures for cleaning up accidental emissions.

Statistical and epidemiologic studies are required to establish the correlation between the presence of nanoparticles in specific ecosystems and disease development in humans and animals, and more especially to evaluate the health risks posed to factory workers. Some nanoparticles would appear to be less harmful than others to living organisms. More research needs to be conducted to allow a better understanding of particle properties (physical and chemical) and to investigate the precise molecular mechanisms associated with nanoparticle toxicity. Long term *in vivo* research will be crucial to determine the effects of nanoparticles over time and to improve our understanding of the acute and chronic effects of nanoparticles on living organisms. Finally, multidisciplinary teams should be set up to evaluate whether the environmental benefits from nanotechnologies can overcome their potential risks and adverse effects. These studies will include all aspects of environmental nanotechnology to determine the real impact of nanotechnology on the environment.

Current programs targeting the social and environmental impacts of nanotechnology

Our analysis of foreign strategies and initiatives devoted to nanotechnologies that could be used or adapted to reconcile the environmental and social issues raised by nanotechnology reveals that US policies in nanotechnology are dominated by federal and state-level initiatives with very diversified objectives, targeting mainly academic research and research institutions. Although private sector organizations are relatively independent of federal initiatives and operate in a fairly autonomous manner, and despite the fact that the US is a market-oriented economy, there have been significant interventions at the federal level to look at the environmental and social dimensions of nanotechnology in parallel with nanotechnology development focusing on commercial or immediate applications.

Nanotechnology policies and initiatives in the US mainly arise from the National Nanotechnology Initiative (NNI), which is controlled by various federal agencies (e.g. NSF, NIH, DOD, DOE, NASA, NIST, EPA etc.). These policies aim to support fundamental research, the creation of infrastructure and centers of excellence, the development of infrastructure, networks and web-based networks or databases on nanotechnology, the creation of special programs to support the social and ethical dimensions of nanotechnology (e.g. the NIRT, NNIN and NSEC programs), and the education of future nanoscientists. In parallel, there are some university-led initiatives which concentrate on the social dimensions of nanotechnology and which support activities to promote an open dialogue between actors from various sectors within the field of nanotechnology and to inform society (e.g. the SPECS association). Similarly, some private foundations, including the Foresight Institute and the Center for Responsible Nanotechnology, are devoted to increasing the level of awareness of the population and policy makers to nanotechnology related issues. The creation of research centers, such as the Center for Biological and Environmental Nanotechnology (CBEN) which is specialized in

fundamental research on environmental issues and application of nanotechnology, or the creation of groups and committees involved in bioethics and the study of the social and ethical dimensions of emerging science and technology (e.g. ASBH, SHHV, President's Council on Bioethics, etc.), are other important bodies that could contribute to supporting nanotechnology stewardship.

Asian countries such as Japan, China and Korea present a quite different picture. For instance, Japan's national initiatives support the public and the private sectors simultaneously. Similarly, several federal Asian agencies include research institutes and private companies which cooperate in tackling nanotechnology issues (CAS 2005). Generally, Asian policies and strategies aim to foster industrial development and to produce economic benefits and real, rapid advancement at the national level in order to improve international competitiveness. Such a philosophy leaves little room for addressing the environmental and social aspects of nanotechnology, which explains why Asian countries lag behind Europe and US in terms of policies designed to address the social and environmental issues of nanotechnology. Moreover, while the US is attempting to develop numerous and diversified fields within nanotechnology, Asian countries such as Japan are focusing on existing skills and industrial capabilities and on staying ahead in fields of traditional Japanese expertise such as semiconductors. In fact, policies formulated in relation to nanotechnology by the Japanese and by the Asian countries more generally, could be qualified as strategic approaches, giving strong State control over nanotechnology development, and allowing little room for independent initiatives.

International initiatives on nanotechnology are not common in Asia and, consequently, these countries operate in a more independent and less cohesive manner. However, the Asia Pacific Nanotechnology Forum (APNF) is an important international initiative that facilitates the coordination of nanotechnology development and programs across the Asian countries. This network includes government policy makers, industry representatives, R&D institutions, and leading researchers and is a formidable asset: it facilitates discussion and exchange of ideas on social and ethical issues raised by nanotechnology. The Northeast Asia Joint Symposium on Nanoscience and Nanotechnology was the precursor to the Asian National Initiative in nanotechnology and supported a common vision on nanotechnology (APNW 2004). Other Asian initiatives that address social, ethical, environmental and educational aspects of nanotechnology include the Research Center for Life Cycle Assessment (LCA), the JEMAI association and the JSPS institution in Japan; some programs developed by the Chinese Academy of Sciences (CAS) in China and the NanoNet network in Korea. NanoNet is a specialized, integrated nanotech information site on the internet and constitutes a network that encompasses scientists, policy makers, students and the general population.

The European Union's nanotechnology policies are very different from those of the US and of Asian countries. European policies appear to strike a balance between a strategic approach aimed at developing industrial and commercial applications of nanotechnologies, and an academic and social vision focused on the returns to society rather than to the economy. EU policies represent an equilibrium between national control and independent initiatives developed by Union members at the national level. Several networks, initiatives and programs have been developed in parallel with central policies to facilitate the development of nanotechnology at various levels. European strategies involve groups of multidisciplinary policymakers, which facilitate the creation of

diversified initiatives. Several committees, programs and initiatives are devoted to different aspects of nanotechnology including R&D activities for academic, industrial and economic applications, and for the social, ethical and environmental dimensions of nanotechnology.

The European Commission, through its Sixth Framework Programme (FP6), which supports the coherent development of R&D policies in Europe, is integrating the environmental, economic, social and ethical impacts associated with emerging sciences such as nanotechnology (FP6 2005). Several European committees or associations (e.g. ESF, EGE, EURAB, EASST, BRTF, ITA, NSC, OMNT, COMETS) and special programs (e.g. ELSA, SINAPSE) have been established to play an active role in the design of science and technology policies, by studying the ethical, social and environmental impacts of particular technologies, including nanotechnology, while other initiatives have supported the formation of networks (e.g. Nanoforum Gateway, LINK, Nano-World) to support education and information diffusion, and to favour interaction between all actors, including scientists, policy makers, industry representatives, civil society, etc.

Recommendations

Science-Metrix has several recommendations to offer with the objective of helping Environment Canada formulate policies and strategies to maximize the benefits, and minimize the risks associated with environmental nanotechnology. These recommendations cover the governance structure, the research infrastructure, the participation of public and private sectors, education, regulatory and legislative frameworks.

Recommendation on the governance structure

Recommendation 1

Science-Metrix recommends that Canadian strategies and policies on nanotechnology take a similar orientation to the European approach. A proper balance between central and independent initiatives will foster an environment that will support nanotechnology development while balancing short and long term perspectives. Balancing economic and industrial development with social, ethical and environmental considerations seems to be the way to favour the sustainable development of this emerging technology. This view serves as a basis for the following recommendations formulated to help Environment Canada in the definition of policies or strategies to adequately identify and minimize issues associated with environmental the nanotechnology.

Although a centralized approach to the development of strategies, initiatives, and R&D activities offers the lure of perfect control, it allows little diversification in terms of ideas, it may stifle innovation and block original solutions to overcoming problems generated by nanotechnology development. To avoid this negative situation, Environment Canada should interact with and mandate independent firms, groups, research centers, etc., and collaborate with foreign institutions, to study and address issues linked with environmental nanotechnology. Moreover, Environment Canada could encourage independent research projects and studies by offering special awards or grants to non university-based individuals and interest groups. Through these collaborations, the visions of nanotechnology developed by Environment Canada's scientists and policy makers can be questioned and reviewed; considered from original perspectives; and refreshed with innovative ideas.

Recommendations on the research infrastructure

Recommendation 2

Environment Canada should create a multifunctional research center devoted to the environmental and social dimensions of nanotechnology. The research center's activities should include research programs to develop environmental application of nanotechnology while other research programs should focus on environmental risks associated with nanotechnology and should explore new approaches to overcome or to minimize these risks. In addition, specific research projects on nanoparticle issues such as nanoparticle toxicity, mechanisms of toxicity, toxicology assay on animal model and characterization of dose-response, ecotoxicology assay, nanoparticle bioaccumulation mechanisms, and the persistence and transport mechanisms of nanoparticles could be studied in this center. Special projects like the development of efficient measuring instruments to detect nanoparticles and the development of standardized risk assessment methods would also be carried out in this research center. In parallel, social scientists could form a task force to study social and ethical issues raised by nanotechnology and work on efficient solutions. The creation of a highly specialized research center in Canada, with a multidisciplinary research team would provide heterogeneous visions and perspectives to specific problems, which in turn would produce more innovative solutions to problem solving.

Recommendation 3

Establish an institution to act as a watchdog, monitor nanotechnology developments, evaluate the relevance of nanotechnology policies and assess the potential issues or risks associated with the utilization of nanotechnology.

Creating institutions as proposed in recommendation 2 and 3 is a costly proposition. There are at least two ways to keep costs down: using existing infrastructures, and establishing virtual institutes on the model provided by the Canadian Institutes for Health Research. Existing infrastructures could be adapted or reoriented to meet the objectives associated with responsible stewardships for nanotechnology. For instance, the National Institute for Nanotechnology (NINT) in Alberta is currently devoted to fundamental research in the field of nanotechnology with a long term objective to develop platforms for building nanosystems and materials that can be constructed and programmed for particular applications. Considering this research center has highly specialized instrumentation and equipment with scientists and qualified staff working in the field of nanotechnology, it could be very advantageous for Environment Canada to negotiate with the NINT to obtain office space or to share costs to enlarge the center to accommodate a complete task force with a multidisciplinary team devoted to environmental and social applications and issues associated with nanotechnology.

Recommendation 4

In addition to establishing a research infrastructure, Environment Canada should work in collaboration with granting councils to establish a grant program to support the work of scientists who would perform research on environmental issues of nanotechnology. In collaboration with the federal granting councils, Environment Canada should provide advice and financial support for grant programs to encourage academic nanoscientists to pursue research on social and

environmental aspects of nanotechnologies. Environment Canada also needs to address the training and education of scientists and the workforce in general, to support the acquisition of skills, knowledge and expertise relating to the environmental aspects of nanotechnology. Science-Metrix recommends that Environment Canada, in collaboration with the granting councils, supports the education of postgraduates in environmental nanotechnology and helps willing provincial stakeholders to develop postgraduate programs.

To increase the expertise of its nanoscientists, Environment Canada should encourage collaboration with foreign universities that have a strong involvement in nanotechnology. Workplace training and student exchanges with relevant universities would contribute to the formation of a core of expertise in nanoscience.

In addition, the development of strong partnerships between Environment Canada and the nanotechnology companies could facilitate workplace training for nanoscientists, allowing the nanoscientists employed by Environment Canada to have access to high tech instrumentation and to become familiar with industry procedures and approaches in nanotechnology.

Recommendation on participation of the public and private sectors

Recommendation 5

A group should be established within the institution that would serve as a watchdog of nanotechnology development (see Recommendation 3) to study the evolution of public attitudes towards nanotechnology. This team would monitor changes in public opinion vis-à-vis nanotechnology, suggest measures to mitigate the risks perceived by the public, and inform Canadians about the steps being taken to secure their safety and well-being. To minimize negative attitudes towards the development of nanotechnology for environmental applications, the public should be informed about the risks and benefits of nanotechnology, and Environment Canada should establish an open dialog with the population and participate in an education campaign. Moreover, open dialog and cooperation with the population, the environment industry and nanotech firms would produce a participative process and foster the development of voluntary measures and stewardship practices.

Reports from the United Kingdom and the European Commission have identified public awareness as a potentially important obstacle to nanotechnology development and recommend strongly that the government must communicate with, and involve as much as possible, the public in the decision-making process in the area of nanotechnologies (EC 2004a; Royal Society 2004). The public should learn about the risks and benefits of nanotechnology. A well informed population allows the elimination of irrational fear or panic concerning the unknown that could lead to the wholesale rejection of nanotechnology.

Environment Canada should facilitate open dialogue and encourage a strong relationship with the public and industry, and should support activities such as workshops, seminars, meetings, and forums to increase awareness of nanotechnologies benefits and potential risks. This group should use a web based network in nanotechnology to diffuse information such as benefits and risks of nanotechnology in regard to environmental, ethical, social and technical perspectives. This network

could serve as a platform to diffuse key reports, articles, initiatives, regulations and policies from Canada and the entire world. It could serve as a forum for discussion groups, and link key people from different sectors including industry, scientific fields, economic sectors, governmental departments, etc. This network could also act as a central point and national reference database to help policy makers, scientists and people from the industry by providing access to a very comprehensive source of information and by facilitating interaction, discussion and partnership between these different players.

Recommendation on regulations and laws

Recommendation 6

Create a Canadian index of potentially harmful nanoparticles for the environment and health with associated standard operating procedures. During a workshop organized by the European Commission in 2004, several international experts proposed a simple and efficient method to minimize environmental and stewardship issues associated with engineered nanoparticles. It has been proposed that all new engineered nanoparticles receive a specific classification number to create an index similar to the Chemical Abstract Service registry numbers that is used for new chemical substance (EC 2004b). Attributing a new, unique classification number to engineered nanoparticles would require toxicology testing and provide information for the Material Safety Data Sheet for nanoparticles as well as for nanoparticles risk assessment and risk management (EC 2004b).

The creation of a Canadian index for potentially harmful nanoparticles for the environment and health would ease the task of regulating the utilization and the release of risky nanoparticles and reduce adverse effects of nanotechnology on environment and society. If potentially harmful and dangerous nanoparticles were chosen for given applications, users would need to follow specific precautionary procedures and standard protocols to minimize associated risks. These protocols and regulations should be established with the cooperation of several federal departments having different competences such as Environment Canada, Health Canada, Natural Resources Canada, etc. This initiative could help Canada reducing long term stewardship issues associated with the uncontrolled use and release of nanoparticles. Environment Canada should also initiate negotiation with other environmental agencies from foreign countries to create an international initiative, allowing the development of a common procedure that will be internationally recognized. This effort must be an international effort to be fully effective.

Recommendation 7

Environment Canada should act as a catalyst in the creation of interdepartmental advisory committees to conjointly establish standards, guidelines, legislations and regulations to protect the environment as well as human and animal health against known issues such as nanoparticles toxicity. For instance, regulations and guidelines established by Environment Canada could address issues such as handling, production and emission of manufactured nanoparticles and products of nanotechnologies, and establish standards and operating procedures for exposed workers. Europeans have already created several committees or groups to work on these issues. For example, the European Centre for Standardization (CEN) working group on nanotechnology focuses on the

establishment of guidelines and standards in nanotechnology; Environment Canada should establish a similar committee in Canada (CEN 2005).

This initiative must be an international effort, in particular with neighbouring countries since developments in the field of nanotechnology could also affect Canada. For example, nanoparticle emission from US industry near the border or near a shared river network could contaminate Canadian environment and Canadians.

Establishment of regulations and standards by Environment Canada will offer a double advantage: it will promote the preservation of a safe environment for people, animals and plants and will contribute to making people feel safe when they see their government acting in a responsible manner. The absence of regulations and responsible actions from federal departments like Environment Canada could create unease in the Canadian population, which could eventually become an important obstacle to the development of nanotechnology similar to that experienced in the diffusion of genetically modified organisms.

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