

Nanotechnology: ‘Risk Governance’ in India

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This article analyses the potential consequences of the application of nanotechnology in the Indian context and studies the institutional arrangements for “risk governance” of nanotechnology in other countries. It is argued that nanotechnology governance in India requires a separate agency – similar to the one established for biotechnology – to develop human resources, infrastructure, and research and to monitor issues and concerns in the field.

We thank the National Science and Technology Management Information System, a division of the Department of Science and Technology, for supporting this study. We also thank Marijke Hermans for her useful comments on an earlier draft.

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In 1959, the Nobel laureate for Physics, Richard Feynman had envisioned the opportunities of exploring the forces and possibilities at the atomic level hinting at what was to become his maxim – “there is plenty of room at the bottom”. Now, over 50 years later, this vision is being carried out in the field of “nanotechnology”. Nanotechnology is usually defined as the understanding and control of matter at the nano-scale (one nanometre is 10^{-9} metre). This is extremely small: just imagine that one hair has a diameter of approximately 80,000 nanometres. At this scale, some materials gain radically new characteristics and functions that can be used for innovative applications in myriads of sectors.

The term “nano” derives from the Greek word νανος, meaning dwarf. Yet contrary to the literal sense the term nano may convey, the field of nanotechnology has come to possess flavours of being a form of “mega-technology”. Governments and companies around the world are allocating sizeable budgets for nanotechnology research and development in order to harness the benefits of what can be found at “the bottom”. Starting with the Nano Science and Technology Initiative (NSTI) in 2001, the Government of India has invested approximately \$400 million so far in creating capacity for nanotechnology research in the country. Although there are some major shortcomings when we compare India’s performance with other economies – that more or less started building capacity at the same time (see for example Bhattacharya et al 2011) – the investments did lead to some tangible outcomes. Today, exactly 10 years after the NSTI was initiated, nanotechnology products are entering the market in increasingly large numbers. It is therefore time to reflect upon the direction nanotechnology developments are taking.

One of the important exercises in capacity building in any emerging technology

is evolving a proper governance structure that includes risk governance. Creating a well-functioning governance structure is a good indication of a country’s capability in making the technology a success. This article specifically looks at the risk-related aspects of nanotechnology, focusing on the Indian context. What are the risks that nanotechnology may pose? What does the Indian situation look like? How can the risks of nanotechnology be adequately dealt with? And, equally important, how can we avoid the, at times, unproductive controversies that have surrounded some of the mega-technologies in the past in order to cast a more fruitful and productive path for nanotechnology’s future?

After briefly sketching some of the potential negative consequences of nanotechnology, we propose a framework of risk governance as a way of dealing with nanotechnology’s development. Our argument not only draws attention to the need for governing risks, but also to the possibility of opening up the larger question about what exactly those risks are and what we want from nanotechnology.

Nanotechnology: Risk Issues

Advocates of technology usually paint a picture depicting technologies as an essential means to achieve economic and societal development. In this view new technologies will inevitably bring benefits of such significance that all other considerations have to give way for the technology’s development. Some caution should be exercised before uncritically buying into this idea. Although there is no question that science and technology have the potential to contribute to societal development, there is a tendency to exclude the potential adverse effects of technologies. In the context of nanotechnology, “we need to realise that new and revolutionary technologies always come as a package – with the promise of new opportunities and the threat of new risks” (AzoNano 2008). Indeed, there is a growing chorus of concerns amongst scientists regarding the issue of toxicity of nanoparticles. The small size of the particles, the same feature that provides nanotechnology with the unique and innovative characteristics and functionalities, possibly

also makes them into a risk for human health and the environment. Nanoparticles, for instance, have a much larger surface area per unit mass than the same material in bulk form, and there can also be differences in their reactivity, bio-persistence, hydrophobic and electrophilic nature, all of which can possibly give rise to undesirable effects (Kjølberg and Wickson 2010; Trudy 2007; Patra et al 2009).

Perhaps unsurprisingly, then, a number of studies have shown that nanomaterials can have adverse effects on living organisms. Studies have revealed that particular nanoparticles can cause damage to lungs and other body tissues (Oberdörster Gunter 2000; Poland 2003; Oberdörster Eva 2004; Oberdörster et al 2007). More specifically, the capability of nanoparticles to cross biological barriers and their increased biological activity in comparison to their bulk counterparts have generated debate on the potential hazards of being exposed to nanotechnology. In an era in which we are witnessing a move from the use and development of “passive nanostructures” to “active nanostructures”, the question of its hazards assumes importance (Kuzma 2007; Subramanian et al 2010). In many cases these toxic properties are different from those of materials outside the nanoscale and subjecting the production and use of these substances to existing legislation is therefore often a difficult task (Gopal et al 2008).

Although these are issues that pertain to technological developments, it is of crucial importance to remember that these do not exclusively belong to the technological domain. Technology and society are no separate, watertight compartments, as they were often perceived in the past. Such techno-centrism often treats any logic to assess technology (e.g., social, ethical, political) other than scientific as hindrance or what they call a “brake on progress” (Rip and Egan 2010). Consequently, discussions on its societal consequences usually take a backseat with respect to the attention given to scientific and economic concerns as they are perceived by scientists and engineers working on the new technologies. However, contrary to this, extensive research in the fields of science and technology studies (STS) and risk studies shows that technologies do not exist in a vacuum. Technologies are intimately intertwined with

societal developments (e.g., Winner 1980; Bijker 1985). Consequently, nanotechnology should also be subject to assessments other than those exclusively focusing on the research output and technical aspects. This also implies that broader societal concerns should be taken into consideration when assessing the development of a technology.

Some concerns have, for instance, been raised about the potentially adverse effects of nanotechnology developments on material demands and consequently on the export of raw materials. For example, when, researchers in the United States succeed in, say, using the new characteristics of materials at the nanoscale to imitate the properties of platinum, then the demand for this rare and thus expensive mineral will be reduced, directly affecting the export rates of its leading exporter, South Africa. Others have drawn attention to the potentially adverse effects of nanotechnology developments on employment rates and an increasing number of commentators (although still a small minority) are asking whether nanotechnology will actually deliver the promises that are driving the investments made in it, particularly in developing countries.

It should be stressed that paying attention to such risks from a societal perspective does not necessarily stop scientific progress. Addressing technological risks can actually contribute to a desirable scientific development and social impact. As we have seen in several European and north American countries, the failure to address issues of risk can give rise to public concerns that may have a backlash on the technological developments. Even more, it may be crucial to do so in order for scientific progress to be safeguarded. Scholars in the field of risk studies have shown many cases in which unduly late or absent attention to such societal consequences forced scientists and engineers to reconsider the direction that technologies were taking, eventually slowing down technologies in comparison with the scenario in which societal effects had been taken into consideration from the start and throughout its development. Technologies are simultaneously technical and social.

Risk Governance

Because of the social nature and societal implications of its use, the task of governing

a technology is not limited to just management and administration of the resources, institutions and the system associated with a technology. It also includes the integration of technological developments with societal needs, in given social, economic, political, environmental and ethical contexts and conditions. Usually this is achieved by what Mihail Roco calls the “government approach” that is creating a regulatory environment to control the role and action of various individuals and institutions by setting up legislations and by ensuring their enforcement (2008). Although such measures are of great importance, it is widely recognised that such a top-down mode of administration is ill-fitted to govern developing and converging technologies for two important reasons. First of all, technological systems are complex and constantly present new perplexities that are difficult to address exclusively through legislative approaches. Secondly, technological systems consist of a large set of actors and agencies that cannot be covered entirely by regulatory tools. In fact, the very nature and application of technologies often keep on changing and knowledge regarding its positive and negative effects is usually not available with a single entity (Corley et al 2009).

In response to this, the discussion on technology governance in Europe, for example, has presently shifted from a top-down authoritative government approach to a bottom up “governance approach” (Commission of European Communities 2001). The concept is not to dilute the role of state. Rather the key difference in the governance approach is the involvement of a variety of other stakeholders in the development of political, economic, and judicial parameters. In order to achieve this, the European Union has spelt out four main principles of governance – openness, participation, accountability, and effectiveness and coherence.

Risk governance is the application of the governance approach to issues of risks and basically refers to the different ways in which various actors are dealing with them. The concept emerged as an alternative to classical notions of risk assessment and management and it differs in two distinct ways. Firstly, risk governance recognises that decisions about issues of risks are not

the exclusive domain of the government (van Asselt et al 2011). In the case of nanotechnology this is already obvious from the fact that scientists and engineers will necessarily be involved. Yet nanotechnology will influence (and is influenced by) other actors as well. For instance, civil society organisations such as The Energy and Resources Institute (TERI) are constructively thinking about the responsible development of nanotechnology (TERI 2010), international organisations such as Organisation for Economic Cooperation and Development (OECD) and International Organisation for Standardisation (ISO) are active, and naturally companies also have some interest at stake when thinking about dealing with nanotechnology risks. The risk governance framework draws attention to this multitude of actors and institutions. As a descriptive framework, it stipulates that the ways risks are dealt with cannot be understood without taking this complex field of actors into account.

This is further strengthened by the observation that matter at the nanoscale is often described as the “building blocks of life”. As such, innovations in nanotechnology are likely to be incorporated across disciplinary and industrial boundaries. For instance carbon-based nanoparticles, better known as carbon nanotubes, are expected to find applications in fields as diverse as solar cells, textiles, construction and sports equipment. A wide range of sectors and consumers are thus likely to be affected. When focusing on the way that risks are dealt with, these actors are likely to enter the arena and affect the way decisions are taken – whether it is through testing for risks, drafting legislation, or by simply not consuming nanotechnology products because of the potential risks. Although this may complicate decision-making in the face of risk, not recognising the multitude of actors may complicate matters even further. In that case a lack of overview and coordination will cause lack of clarity about responsibilities and may lead to a duplication of efforts, an issue that has previously been discussed (Chowdhury 2006).

The second distinct feature of the risk governance framework is that it is particularly useful in the case of uncertainties about them. Although this may seem a

tautology (after all, risks necessarily involve uncertainty about the effects), the additive “uncertain” nevertheless offers some added value in an influential study by van Asselt et al (2008: 281):

The notion uncertain risks refers to possible, new, imaginable hazards, with which society has no or limited experience. It is uncertain whether the particular activity, product or phenomenon constitutes a risk to humans and/or the environment, because causalities are complex, the possible multiple effects are heterogeneous and extend to the long-term and/or the global scale and risk perceptions clash.

Nanotechnology offers an instructive example. The risks associated with nanotechnology are to a large degree characterised by uncertainty. For instance, there is inadequate information about how nanoparticles interact with human body tissues, and knowledge is lacking about both the acute toxicity and the long-term effects of nanoparticles (Gopal 2008: 25-32). Similarly, the environmental impacts of nanoparticles are also largely unknown. Although some studies have demonstrated that specific nanoparticles can potentially pose risks for human health and environment, both to what extent they inflict harm and how they do so thus far remain unknown. As was written in *Nature* in 2009,

...developers and regulators are a long way from understanding how to predict and manage the potential risks associated with existing nanomaterials, let alone those in the pipeline (Maynard and Rejeski 2009: 174).

Contemporary observers have noted the uncertainties about both the risks and benefits that inevitably accompany new technologies often making standard forms of decision-making inadequate (Funtowicz and Ravetz 1993). Such uncertainties, for instance, make it hard to perform quantifiable risk assessments in order to establish a clear threshold value for commercialising nanotechnologies. When risks are nevertheless quantified into classic risk assessments, then this may not only be misleading, but may also actually contribute to what has been called “organised irresponsibility” (Beck 1992). Yet the indications that at least some nanoparticles may pose a threat to human health and the environment are genuine, as shown above. Consequently, even if quantitative risk assessments cannot be made, action is justified. After all, if no action is taken but the

uncertain risk turns out to be real risk, then the technology may have caused significant damage in the time it took to figure out whether the risk was real.

Following the risk governance framework, the last decade has witnessed a rise in scholarly work that thinks about ways of dealing with technological risks in the context of uncertainty and complex actor-relations. When applying this framework to the case of nanotechnology, several issues gain new importance. For instance, the uncertainty requires the governance of nanotechnology risks to be anticipatory and flexible. It needs to be anticipatory because the knowledge needed for dealing with those risks is inconclusive, whereas not dealing with the potentially harmful properties of nanoparticles can lead to even larger damage. It needs to be flexible because new knowledge can shed new light on the issues of risk. Furthermore, the risk governance framework draws attention to issues such as the trust between the different actors (Löfstedt 1993) and the relevance of other forms of knowledge than scientific knowledge (for instance in recognising “early warnings”) (Wynne 1982; Harremoës et al 1992).

Before we look at the Indian context and ask to what extent the issues raised by the uncertain risks of nanotechnology can be dealt with, the next section will show some of the ways that other countries currently deal with nanotechnology risks (Table 1, p 37). This will illustrate some of the possible ways in which risk governance can be made operational.

The Indian Context

Keeping the above risk governance frameworks in mind, let us have a look at the Indian context. Since the 1980s science and technology policies in India started concentrating on research in high-priority fields. As a result, in the Sixth Five-Year Plan (1980-85), the programme for Intensification of Research in High Priority Areas (IRHPA) was launched to ensure intensification of scientific research in selected areas of potential for scientific and technological development of the country. This was proposed to be achieved through the creation of core scientific expertise, technological facilities, nationally coordinated programmes in multidisciplinary areas (DST 2003).

Table 1: Initiatives by Different Countries

Country	Key Coordinating Body	Supporting Bodies	Key Legislations/Code of Practices
US – multiagency governance at various levels. Command and control mode	Nanoscale Science Engineering and Technology Subcommittee	National level – (National Science Foundation) – Research Regulation. – (Presidential council of advisors on science and technology) – NT initiative review. Agency level – Food and drug administration, – National institute for health, – National Institute for occupational safety and health, Nanotechnology environmental and health implication working group Programme level – (Committee of visitors) – evaluation through stakeholder inputs – (Advisory boards) – R&D programmes review	Nanotechnology Research and Development Act (2003) Food Drug Cosmetics Act Toxic Substance Control Act (2005) Occupational Safety and Health Act.
UK – State-coordinated governance with involvement of academia, learned communities and stakeholders	Nanotechnology Issue Dialogue Group	– Nanotechnology research coordinating group (Departments for environment, food and rural affairs, health food standards, – Learned Societies, The Royal Academy of Engineering, The Institute of Materials, Minerals and Mining, UK Programme of Public Engagement on Nanotechnologies Nanodialogues)	Guide to safe handling and disposal of free engineered nanomaterials Guide to specifying nanomaterials Good Practice Guide – for labelling of nanoparticles and products containing nanoparticles
Japan	No specific coordinating body. Council for science and technology policy – NT policies	National Institute of Advance Industrial Sciences National Institute of Material Sciences	Chemical screening and regulation law
China	National Steering Committee for Nanoscience and Nanotechnology	– Ministry of science and technology – Ministry of education – Chinese Academy of Sciences – National Natural Science Foundation of China	

Currently nanotechnology is one of the fast developing technological fields in India and it enjoys a major share of public funding. In 2001, the Government of India, represented by its line departments such as Department of Science and Technology (DST), the Department of Information Technology (DIT), the Indian Council of Medical Research (ICMR), the Department of Atomic Energy (DAE) and the Defence Research and Development Organisation (DRDO) started to build capacity in nanotechnology. Indian nanotechnology initiatives are government-led programmes, but gradually also other players such as industry, research institutes and civil societies have started engaging in it. The DST is the prime agency engaged in the development of nanoscience and technology. One of the key features of the nanotechnology policy was the promotion of basic research (DST 2007). However, until recently, there has been almost no research on the environment, health and safety aspect of nanotechnology nor has there been much attention to other potential adverse effects of nanotechnology development.

This is not necessarily a surprise. Out of the three science technology policy statements released in India, only the 1983 technology policy statement makes a small reference to the need to analyse the environment impact of the application of

technologies (DST 1983). Yet in practice, these concerns have been mostly neglected. As in many other countries, publicly-funded research in India is mostly driven by educational and commercial interest. This can be well understood as it is widely recognised that under certain conditions research can contribute to achieving economic growth through the development of improved technologies. Yet whereas technologically advanced countries like the United States and the United Kingdom try to accompany such technology development with all sorts of governance arrangements in order to ensure the responsible development of new technologies, in India attention to issues of risk is minimal. Rather than explicitly taking broader societal concerns into consideration when promoting the development of a technology, it seems that any kind of measure to deal with potential adverse effects of new technologies is considered as inimical to market investment in technology sectors. By and large, the Indian state has shown a lack of anticipatory governance during the course of technology development.

Consequently, it has been observed that attention to risk issues has surfaced only within the government after there has been a considerable public debate over any technology. This, for instance, occurred in the recent public debate about the

introduction of genetically modified Bt brinjal. The case attracted attention from various stakeholders including the public. The approval for Bt brinjal by the Genetic Engineering Approval Council was challenged by civil society as well as by eminent scientists. P M Bhargava, India's renowned molecular biologist, pointed out that approval was made without testing it properly within the existing guidelines. Consequently, strong public resentment led to the placement of a moratorium by the Government of India on the commercial release of Bt brinjal in February 2010.

Environmental, Health and Safety Issues

During the NTSI phase (2001-06) discussions on risk were totally missing. One of the reasons was that the sole priority of the programmes was to create a strong institutional base, infrastructure support and skilled manpower. In this period, government machinery was trying to situate nanotechnology as a field of research within the network of research institutions and develop expertise and applications. With the launch of the Nano Science and Technology Mission (NSTM) in 2007, the governmental initiative saw some structural changes. First of all, the inward focus to develop nanotechnology research and application within public institutions was

replaced by a broader focus of public-private partnership. This resulted in the inclusion of members from industry in research bodies that were previously dominated by scientists from public research institutes. Second, the NSTM unlike the NSTI focused on arrangements to take the output of laboratory research from basic to applied research and applications. This is precisely where concerns regarding the impacts of nanotechnology arise.

Meanwhile the European Union and the US have already introduced regulatory systems in order to assess hazard and exposure risk. The EU has developed regulatory frameworks for nanomaterials in industrial and chemical products in fields such as cosmetics, food and the environment through key legislative instruments (Bowman and Calster 2010). These legislations and directives regulate products such as plant protection products, biocides, cosmetics, aerosol dispensers, medical products, cars, food, chemicals and worker protection. Under environmental legislation, aspects such as integrated pollution prevention and control, major accidents, water waste, air quality, soil and environmental liability are addressed. In addition, the EU is currently in the process of adapting the regulatory framework Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (UNESCO 2006) in order to make it applicable to nanotechnologies. In the US, agencies like Environmental Protection Agency (EPA), Food and Drug Administration (FDA), and the Occupational Safety and Health Administration have promoted various research projects to understand the potential risk of nano-engineered materials to ensure safe manufacturing and commercialisation of nanotechnology products.

Regulating nanotechnology is challenging due to the intrinsic characteristics of nanotechnology. Its multi-sectoral application makes it difficult to address the various aspects of this technology by a single regulatory agency and under an exclusive regulatory framework (Corley et al 2009). Yet whereas countries such as US, UK, Canada, Japan and China are working hard to create governance arrangements (including regulatory mechanism) to address risks related to nanotechnology, India has only a loose framework of legislation where

nanotechnological risks can be addressed. In terms of regulations India has a high number of legislations that address pollution control, environmental protection, hazardous waste disposal, biomedical waste disposal, safe manufacturing of drugs, and occupational health and safety. However, none of these acts and legislation have explicitly identified nanoparticles as a hazard. A recent analysis of such issues in a report released by the TERI suggests that the level of flexibility within the present legal regime is insufficient to deal with the ill-effects that nanotechnology may have on health and environment (TERI 2010).

Table 2: Risk Research on Nanotechnology in India

Toxicology research:
– Indian Institute of Toxicology Research (IITR)
– Indian Institute of Chemical Technology (IICT)
– Central Drug Research Institute (CDRI)
– Central Food Technology Research Institute (CFTRI)
– National Environmental Engineering Research Institute (NEERI)
– National Chemical Laboratory (NCL)
– National Institute of Oceanography (NIO)
Focus on effects of nanomaterials on human health and environment:
– Technology Information, Forecasting and Assessment Council (TIFAC)
– National Institute of Science, Technology and Development Studies (NISTADS)
– Indian Council of Agricultural Research (ICAR)
Developing regulatory approval guidelines for nanotechnology-based drugs and standards for toxicological tests in nano-based drug delivery systems:
– National Institute of Pharmaceutical Education and Research (NIPER)

Regarding the risk assessment of nanotechnology applications, the UNESCO has specified some of the important directions that countries should pay attention to begin or strengthen nanotechnology risk governance. The first area concerns biological and chemical effects of nanoparticles on human bodies and natural ecosystem. The second area concerns the disposal (leakage, spillage, circulation and concentration) of nanoparticles (UNESCO 2006). Recently, a number of studies on the toxicity aspect of nanotechnologies have indeed been initiated by the DST and its related departments recently under NSTM to study the toxicity, environmental and health implication of nanomaterials (DST 2010) (Table 2).

Yet, although this is a positive development, it is doubtful whether this will

suffice. The uncertainty associated with the present knowledge in this domain makes it difficult to craft a regulatory framework that covers all the facets of nanotechnology. Presently, the available knowledge on the potential impacts on nanotechnology on social, economic, environmental and human health is insufficient. And has been recently argued by Grieger, Baun and Owen (2010), filling those knowledge gaps will be very expensive and will take a long time. They note that “a recent analysis estimates that testing existing nanoparticles in the US alone will cost between \$249 million and \$1.18 billion and take 34-53 years for completion” (2010: 385). Now of course India can benefit from research done abroad, but all in all, given the status of nanotechnology development in India and the amount of knowledge available on its nature, intensity and impacts, a technology specific legislation is hard to imagine (TERI 2010). Consequently, other ways for dealing with nanotechnology risks should be found that do not exclusively rely on risk assessments. Following the risk governance framework, the various actors involved should jointly look for more proactive ways of dealing with potentially adverse effects of nanotechnology. In India we find various entities involved in nanotechnology governance. Figure 1 (p 39) gives a stylised representation of different stakeholders involved in nanotechnology governance in India.

Lack of Coordination

Nanotechnology development in India is suffering from a lack of coordination as we find multitude of bodies involved in nanotechnology development. The DST is the coordinating body for the major government programmes on science and technology including nanotechnology. However, its mandate does not include risk governance. But whereas a major category of risk-related areas come under the responsibility of Ministry of Environment and Forest (MOEF), none of the acts and legislation of MOEF has explicitly identified nanoparticles as a hazard. Furthermore, potentially adverse effects of nanotechnology that fall outside the scope of environmental, health and safety aspects, such as the question as to how nanotechnology developments relate to the export of raw materials

Figure 1: Regulatory Framework for Nanotechnologies in India

		EHS	ELSI
Public Sector	Ministry of Science and Technology	DST	Nano Mission Council (Regulatory Body)
		DSIR	CSIR CSIR LABS (Toxicology Research)
			CSIR-NISTADS
	DBT	Universities (Toxicology Research)	
	Ministry of Environment and Forest (Various acts formulated to deal with different hazards of environment)	Central Pollution Control Board	State Pollution Control Board
Ministry of Chemical and Fertilisers	Department of Chemicals and Petrochemicals		
	Department of Pharmaceuticals		National Institute of Pharmaceutical Education and Research (EHS, Drug Regulation, Toxicity Testing of Drugs)
Ministry of Labour and Employment (The Factory Act (1948))	General Factory Advice Service and Labour Institutes [Advisor Occupational Health Safety (OHS)]	National Safety Council (OHS Education)	
Ministry of Health Family and Welfare (Drugs and Cosmetics Act 1940, amended in 2008)	Central Drug Standard Control Organisation (EHS)		
	ICMR (EHS Issues)		Central Drug Research Institute (Regulatory toxicology)
	Food Safety Standard Authority of India		
Ministry of Consumer Affairs (The Consumer Protection Act 1986)	Department of Consumer Affairs		
	Bureau of Indian Standards (standard development in nanotechnology)		
Private Sector			TERI
	Non-governmental Organisations		FICCI

or whether nanotechnology will be beneficial for employment rates, have hardly been addressed at all. Debates on the risk that this technology may pose are yet to begin in India. Only in 2010, the DST appointed a task force that has been asked to advise the Nano Mission Council to develop a regulatory body for nanotechnology in India.

Currently the nanotechnology programme planning and implementation largely remain restricted within the domain of science and technology. Other major stakeholders, including the private sector and civil society, are insufficiently involved. This situation may be improved if there is a coordinating body that can bring the different institutions together. One option could be to establish an interagency nanotechnology regulatory agency. Following a multi-stakeholder engagement approach,

such an agency can develop nanotechnology plans within each major regulatory agency and improve intergovernmental coordination. The focus of the Interagency Nanotechnology Regulatory agency should be broader than science-based government regulations and can facilitate the development of more proactive ways of dealing with risks.

Finally it should be noted that the success of nanotechnology and the prevention of its adverse effects ultimately rest with the private sector. No amount of government policing will work without cooperation from nanotechnology firms. However, history has shown that it would be a mistake to rely solely on the free market. Although we have argued here for opting for a governance approach rather than a government approach, it should be stressed that

voluntary efforts are a supplement to, not a substitute for, government oversight.

Conclusions

The multifaceted dimensions and implications of nanotechnology do not fit into the compartments delineated by the present regulatory framework in India. An effective risk governance system is urgently required both because of the inadequate picture of present nanotechnology regulatory scene and because of the perplexities presented by technological advancements. While leading nanotechnology nations are debating on the best strategy to ward off risk, Indian government has so far adopted a “learn by doing” approach in nanotechnology development. However, it is high time India’s science and technology research bodies showed some seriousness towards nanotechnology risk governance.

We argue that nanotechnology governance in India requires a separate agency similar to one undertaken for biotechnology, to develop human resource, infrastructure, active research network, common sharing of facilities, and monitor the issues and concerns of nanotechnology. Such an agency should be aided with scientific insights on risk based on quality research on toxicity, exposure, hazards of various nano components as well as by “early warnings” and supplied by other actors such as industry, civil society, and the public. The various centres of excellence in India can have important role in taking initiative in this direction. Coordination is urgently needed to serve as a baseline even for synergising the working of multiple institutes. Only by creating such a well-functioning governance structure can India make nanotechnology into a success.

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