Global Dialogue on Nanotechnology and the Poor: Opportunities and Risks

Workshop on Nanotechnology, Water & Development

Workshop Summary

10-12 October 2006 | Chennai, India
# nanotechnology, water, & development

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Appendix 1: Workshop on Nanotechnology, Water, and Development Agenda ......................................................... 23
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Nanotechnology refers to a wide range of technologies that measure, manipulate, or incorporate materials and/or features with at least one dimension between approximately 1 and 100 nanometers (nm). Such applications exploit the novel properties that result from the nanoscale components’ unique physicochemical and surface properties.

Both the public and private sectors in developed and developing countries, including developing countries with strong research and development capacity such as Brazil, China, India, and South Africa, are investing heavily in nanotechnology research and development. Despite rising nanotechnology investments and a proliferation of applications, only a limited number of people are exploring the linkages between nanotechnology and critical human development needs.

To close the gaps between people working on nanotechnology and those working on international development, Meridian Institute convened the Global Dialogue on Nanotechnology and the Poor: Opportunities and Risks (GDNP) with the following goals:

1. Raise awareness about the implications of nanotechnology for the poor;
2. Close the gaps within and between sectors of society to catalyze actions that address specific opportunities and risks, especially those of significance to developing countries; and
3. Identify ways that science and technology can play an appropriate role in the development process.

As one of several activities in the GDNP process,1 Meridian Institute convened the International Workshop on Nanotechnology, Water, and Development (Water Workshop) on 10-12 October 2006 in Chennai, India to address the potential opportunities and risks of nanotechnology water purification technologies for developing countries.

Millions of people in developing countries are affected by the lack of potable water. Lack of access to clean water affects the livelihoods of the world’s poor. Ensuring that communities have access to clean water is of paramount concern. Nanotechnology promises new or improved solutions to challenging obstacles to providing clean water. Since some nanotechnology solutions for water purification are already available and human development needs for clean water are pressing, some people have identified the exploration of nanotechnology for water purification as a priority issue.

Water Workshop participants from developed and developing countries and with a broad range of perspectives and expertise discussed the range of challenges people in developing countries may face when developing and implementing strategies for improving basic sanitation and access to clean water. Building on a shared understanding of these challenges, participants discussed opportunities for using nanotechnology to address water supply and sanitation challenges, and risks and other issues that need to be addressed in relation to specific nanotechnology applications.

During these discussions, participants reviewed technical characteristics of specific applications or classes of applications and then expanded their discussions to focus on cross-cutting issues, using the matrix described in Section 4. During those discussions, participants raised a number of cross-cutting issues that are broadly applicable across the range of nanotechnology applications discussed at the workshop, including the following:

- Product research and development – Participants discussed the stages of development of specific nanotechnology applications, which informed discussion of the implications and cross-cutting issues associated with these technologies (e.g., a technology that is already on the market may raise different governance, risk, or IP issues than a technology that is just being tested in a laboratory).
- Environment, human health, and safety risks – Participants identified the need for additional risk research regarding nanoparticle release and exposure risks during production and use; spent waste and used cartridge disposal; and nanoparticle concentrations in output water.
- Socio-economic issues – Some participants expressed concern that nanotechnology applications may make technology users dependent on technology suppliers, while others suggested that certain nanotechnology applications could enable local production of new solutions to water treatment.
- Ethics – Participants discussed ethical issues related to the tension between developing new options for water treatment that could benefit poor communities, and the need to assess and manage potential new risks associated with these options. Participants also raised issues regarding labeling of products that incorporate nanoscale materials.
- Intellectual property rights and access – Some participants raised concerns about the ability of a few actors to control access to new technologies if sweepingly broad patents on nanotechnologies are granted and patent ownership is consolidated.

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2 To inform these discussions, Meridian provided the following background papers: Nanotechnology, Water, and Development: Overview and Comparison of Conventional and Nano-Based Water Treatment Technologies; Examples of Enabling Technologies for the Development of Nano-Based Water Treatment Technologies; and Water and Development News Compilations.
Public participation and engagement – Participants identified a need for technology assessment tools that would help community members assess and identify appropriate technologies for water treatment in their household, community, municipality, or upstream. They also suggested that these assessment tools could be designed to help communities determine appropriate water quality standards for various uses.

Governance – Participants discussed existing systems for governance of nanotechnology, and specifically discussed the role of government and other actors in governance systems. Participants identified several governance needs, including a need for a clear definition of nanotechnology, a framework to categorize classes of technology, early listening systems for government agencies in developing countries, as well as human, financial, information and other resources.

Capacity building – Participants discussed capacity building that includes all sectors of society to ensure that technology adoption is sustainable.

International collaboration and cooperation – Participants identified specific opportunities for collaboration and cooperation, as described in Section 7 “Next Steps.”

Scalability, delivery, and sustainability – Participants noted that both conventional and nanotechnologies require strong local partners for distribution and adoption. Several participants noted the cost of energy inputs needed for many water purification technologies.

Participants reviewed technical characteristics of the following specific nanotechnology applications or classes of applications. Participants made a number of technology-specific comments, which are summarized in the tables in Section 6.

- Nanofiltration and nanofiltration membranes – Participants discussed the Long Beach Method for desalination and the nanofiltration plant developed by Malutsa in South Africa that incorporates Filmtec CTCI and NF270 filters and was the subject of one of the case studies in the Paper on Nanotechnology, Water, and Development.
- Nanostructured clays – Participants discussed hydrotalcite, a nanoclay for which CSIRO in Australia has developed a process that enables low-cost, local production of synthetic anionic clay called hydrotalcite that can be used to remove arsenic and possibly fluorides from water and groundwater.
- Nanocatalysts – Participants discussed the enhanced catalytic capabilities of several nanotechnology applications, including a nanoparticle filter developed by the Indian Institute of Technology and commercialized by Eureka Forbes in India, a carbon nanotube-based photocatalysis system developed by Monad Nanotech in India, and magnetic nanoparticles being developed at Rice University in the US, magnetic nanoparticles incorporated in a filter being pursued by Tata Chemicals in India, and magnetic nanoparticles developed at the University of Brasilia in Brazil.

Participants also provided brief descriptions of several types of nanobased sensors for detecting contaminants in water, and discussed their applications.

This event helped create new and unique connections between communities of people, and resulted in important insights that will inform future multi-stakeholder discussions on nanotechnology and development. The Water Workshop confirmed the power of sector-focused discussions to inform and focus dialogue on the opportunities and risks of nanotechnology for developing countries. Workshop participants identified follow-up actions that Meridian Institute and others are now pursuing, including:

- Developing and disseminating more robust general information about nanotechnology, water, and development through publications and websites.
- Improving resources for helping people compare nanotechnology-based and conventional products for improving sanitation and access to clean water.
- Addressing cross-cutting issues in the context of specific technologies;
- Developing broader networks of people interested in these issues, in part through utilization of information technology tools.
- Organizing additional workshops on topics pertinent to nanotechnology and development (e.g., commodities, nanotechnology and development and water, nanotechnology and development).
- Exploring nanotechnology governance, especially those issues of most significance and interest to developing countries.

Although these activities are focused on issues related to nanotechnology, water, and development, they also set the stage for future discussions about other sectors (e.g., commodities, and energy) and about broader issues such as nanotechnology governance.

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[2] Introduction

Nanotechnology encompasses a broad range of tools, techniques, and applications and is widely perceived as enabling significant technological advancements in numerous sectors. Engineered nanomaterials are manufactured materials with a structure between approximately 1 nanometer (nm) and 100 nm. Their unique physicochemical (e.g., size, shape) and surface (e.g., reactivity, conductivity) properties contribute to the development of materials with novel properties and technical solutions to problems that have been challenging to solve with conventional technologies.

Both the public and private sectors are investing heavily in nanotechnology. Over 20 countries, including developing countries such as China, South Africa, Brazil, and India have national nanotechnology programs, and many more are developing or expanding nanotechnology research and development (R&D) capacity. The collective public sector investment in 2005 was approximately US$4.6 billion. Private sector investments, including venture capital, added an additional US$5 billion. Total investments were up 10% compared to 2004.[1] In addition to growing investments in research and development, the number of patents on nanotechnology-related inventions and scientific literature citations continues to skyrocket. Nanoscience is clearly advancing at a rapid pace.

With nanotechnology investments continuing to rise and applications proliferating, awareness and understanding regarding the implications of nanotechnology for developing countries is increasing. However, this awareness is still generally limited – few people involved in nanotechnology are considering development issues; few people involved in the development community are considering the potential role of nanotechnology in addressing critical development needs. These gaps are a significant concern, as current decisions in both developed and developing countries may result in policies, practices, and systems that can have long-term impacts on the role of nanotechnology in helping to address specific development needs.

The Global Dialogue on Nanotechnology and the Poor: Opportunities and Risks (GDNP) is intended to close these gaps by providing information and raising awareness about nanotechnology issues among people in governments, industry, academia, international institutions, and non-governmental organizations (NGOs) that focus on development; and to raise awareness about development issues among people who are focused on nanotechnology or, more broadly, science and technology issues.

To address these gaps, the GDNP was established with the following goals.

[1] Raise awareness about the implications of nanotechnology for the poor;
[2] Close the gaps within and between sectors of society to catalyze actions that address specific opportunities and risks, especially those of significance to developing countries; and
[3] Identify ways that science and technology can play an appropriate role in the development process.

For approximately two years, Meridian Institute has pursued these goals through a variety of activities that have included, for example: convening meetings to identify the core issues at the nexus of nanotechnology and development; distributing timely and balanced information through our Nanotechnology and Development News service; speaking about nanotechnology and development at conferences; catalyzing and supporting collaborations and actions focused on specific opportunities and risks. Detailed overviews of these past and on-going GDNP activities can be found at http://www.merid.org/nano.

As part of the GDNP process, Meridian Institute convened the International Workshop on Nanotechnology, Water, and Development (Water Workshop) on 10-12 October 2006 in Chennai, India to address the potential opportunities and risks of nanotechnology water purification technologies for developing countries.

Discussions at the Water Workshop focused, in particular, on increasing understanding about nanotechnology applications relevant to water supply and sanitation challenges in developing countries and identifying activities that would inform decisions and catalyze actions by stakeholders (e.g., water experts, development experts, governments, NGOs, companies, universities, international institutions, and donors) involved with:

- Nanotechnology research and development efforts relevant to providing clean water in developing countries; and
- Activities to address potential environmental, health, safety, socio-economic, and other issues related to the use of nanotechnology in water treatment devices.

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Workshop participants discussed challenges people in developing countries may face when developing and implementing strategies for improving basic sanitation and access to clean water. Discussions focused on a range of issues including production and distribution of technology; access to technology; socio-economic issues; environmental, health and safety risks; governance; and the appropriate role of science and technology in international development.

With a shared understanding of this broader context regarding water supply and sanitation, participants discussed to what extent nanotechnology presents opportunities for addressing water supply and sanitation challenges, and what are the risks and other issues that need to be addressed in relation to specific applications. Participants discussed specific applications of nanotechnologies and explored a range of cross-cutting issues (e.g. governance, risk assessment, cost-effectiveness, intellectual property, and scale-up) in the context of these specific examples.
Access to clean water is of paramount concern from a human development perspective. The world’s poor are most affected by the lack of potable water because it is predominantly they who depend directly on water and other natural resources for their livelihoods. Water is important as an input into production, for maintaining health and welfare, and for ensuring ecosystem integrity. Ensuring that communities have access to water resources has become widely equated with ensuring that the basic human needs are met.

Researchers, policy makers and others have repeatedly mentioned the promise of nanotechnology applications to contribute new or improved solutions that meet human development needs. Nanotechnology for water purification has been identified by some people as a high priority area because water treatment devices that incorporate nanoscale materials are already available and human development needs for clean water are pressing.

Given the growing interest in these issues, Meridian Institute, through the Global Dialogue on Nanotechnology and the Poor, convened the Water Workshop to provide a venue for people with diverse expertise and viewpoints to discuss the potential opportunities and risks of nanotechnology in relation to water supply and sanitation challenges in developing countries. In preparation for the workshop, Meridian Institute developed four background papers on nanotechnology and water purification.

- **Nanotechnology, Water, and Development** – Provides information about the scale and significance of water and sanitation problems in developing countries, the broad array of challenges associated with improving access to water, and the possible opportunities and risks of using nanotechnology to address these challenges. This paper was written by Thembela Hillie of the Council on Scientific and Industrial Research in South Africa, Mohan Munasinghe and Yvani Deraniyagala of the Munasinghe Institute for Development in Sri Lanka, and Mbhuti Hlope of North West University in South Africa with staff from Meridian Institute.

- **Overview and Comparison of Conventional and Nano-Based Water Treatment Technologies** – Written by Meridian Institute staff as a supplement to “Nanotechnology, Water, and Development,” this paper provides a comprehensive document that facilitates comparisons of conventional and nanotechnology-based water treatment devices.

  - **Examples of Enabling Technologies for the Development of Nano-Based Water Treatment Technologies** – This hand-out written by Meridian Institute staff provides examples of some enabling (i.e., platform) technologies that may help with the affordability and scalability of nano-based community and household level point-of-use (POU) water treatment methods.

  - **Water and Development News Compilations** – The Nanotechnology and Development News (NDN) Water Compilation is a compilation of all water-related news summaries published since the launch of NDN by Meridian Institute in 2005.

These materials are available from the Water Workshop website at: [http://www.merid.org/nano/waterworkshop/](http://www.merid.org/nano/waterworkshop/).

The workshop began with brief presentations by two of the co-authors of Nanotechnology, Water, and Development on the case studies included in that paper describing projects designed to improve access to clean water.

- **A case study set in Bangladesh that provides an example of a simple, affordable, and reportedly successful conventional (non-nano) technology designed to remove cholera bacteria from water**. This case study was included to illustrate the range of issues that must be considered when developing projects for improving access to clean water (e.g., effectiveness, community acceptability, costs, and sustainability).

- **A case study in South Africa describes a project using nanofiltration membranes to provide clean drinking water to rural communities**. It provided an example of a technology-based approach for addressing water and sanitation challenges in a rural village in a developing country.
The presentations were followed by a plenary discussion during which participants identified a wide array of cross-cutting issues related to nanotechnology, water, and development to be discussed in more depth later in the workshop (i.e., issues that apply across the spectrum of nanotechnology applications under discussion). Participants noted that these issues are also likely to be relevant to nanotechnology applications in other sectors such as commodities, energy, and health.

These issues included, but were not limited to:

- Product research and development
- Environment, human health, and safety risks
- Socio-economic issues
- Ethics
- Intellectual property rights and access
- Public participation and engagement
- Governance
- Capacity building
- International collaboration and cooperation
- Scalability, delivery, and sustainability

Meridian Institute staff developed a matrix listing these issues and the classes of nano-based water treatment technologies identified in the background paper, *Overview and Comparison of Conventional and Nano-Based Water Treatment Technologies* (Figure 1). Participants used the matrix throughout the meeting to help guide and focus discussions on issues associated with specific nanotechnology-based water treatment technologies.

Meridian Institute suggests the following definitions to clarify the distinguishing characteristics of these cross-cutting issues, while recognizing that there is some overlap and important connectivity between them.

### Product Research and Development
Systematic activities to increase knowledge and apply it to the (further) development of new applications. In the context of the workshop, participants focused on assessing the maturity of specific nanotechnology applications and the steps that would be necessary for further development.

### Environmental, Human Health, and Safety Risks
Potential harm that may arise from a material, combined with probability of an event (e.g., exposure). In the context of this document, the focus is on potential risks to the environment, human health or worker safety.

### Socio-Economic Issues
Impacts on individuals, institutions, or society resulting from a policy or project (e.g., the introduction of a product, of a market intervention) such as price changes, welfare changes, and employment changes.

### Ethics
A branch of philosophy concerned with evaluating human action, in particular what is considered right or wrong based on reason. In the context of nanotechnology, ethical questions have focused, for instance, on applications related to human enhancement and performance, privacy questions resulting from research into nanotechnology monitoring systems, and questions about possible malevolent or military uses of nanotechnologies.

### Intellectual Property Rights and Access
Intellectual property rights (IPRs) are legal protections for intellectual property claimed by individuals or institutions. Copyrights, patents and trademarks are common mechanisms for protecting intellectual property. IPRs are intended to spur innovation and commercialization, but may limit the ability of individuals and institutions to access technology.

### Public Participation and Engagement
Processes that affect whether and how individuals participate in societal discourse, including public information, public education, and public discussion and dialogue regarding nanotechnology.

### Governance
Processes, conventions, and institutions that determine how power is exercised to manage resources and societal interests, how important decisions are made and conflicts resolved, how interactions among and between the key actors in society are organized and structured, and how resources, skills and capabilities are developed and mobilized for reaching desired outcomes. This includes risk governance (i.e., comprehensive assessment and management strategies to cope with risk) and governance for innovation (i.e., programs targeting nanotechnology R&D for public objectives). Using this definition, governments, governmental and intergovernmental institutions, as well as public and private corporations, non-governmental organizations, and informal associations are examples of institutions involved in governance.

### Capacity Building
Assistance provided to develop a certain skill or competence, including policy and legal assistance, institutional development, human resources development, and strengthening of managerial systems.

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**Table: Matrix of Technologies and Cross-Cutting Issues**

<table>
<thead>
<tr>
<th>Product Research and Development</th>
<th>Environmental, Human Health, and Safety Risks</th>
<th>Socio-Economic Issues</th>
<th>Ethics</th>
<th>Intellectual Property Rights and Access</th>
<th>Public Participation and Engagement</th>
<th>Governance</th>
<th>Capacity Building</th>
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</table>
**International Collaboration and Cooperation** – Collaborative partnerships between individuals, and institutions from developed and developing countries at a local, national, regional level on any aspect of nanotechnology including North-South (i.e., developed and developing) and South-South (i.e., developing – developing)

**Scalability, Delivery, and Sustainability** – The ability to scale-up production and distribution of products so they reach large numbers of people (i.e., success not limited to pilot projects) and the sustainability of products, which relate to numerous factors including, for example, costs, ease of use, and durability.

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**Figure 1. Matrix of Nano-Based Water Treatment Technologies and Cross-Cutting Issues**

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<tr>
<th>Water</th>
<th>Carbon Nanotube Technologies</th>
<th>Nanofiltration</th>
<th>Nanofibrous Filters</th>
<th>Nano-Ceramics, Clays, and Adsorbents</th>
<th>Zeolites</th>
<th>Nanocatalysts</th>
<th>Magnetic Nanoparticles</th>
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</table>
Cross-Cutting Issues

Throughout the meeting, in both plenary sessions and workgroups, participants discussed specific nanotechnology applications relevant to water and sanitation challenges. During these discussions, participants began by reviewing the technical characteristics of specific products or classes of products and then expanded their discussions, using the matrix (above) as a guide, to focus on cross-cutting issues.

In the section below, comments and perspectives that are broadly applicable across the range of nanotechnology applications discussed at the workshop are described. Following these generally applicable cross-cutting comments are specific descriptions of the applications discussed and information unique to those applications (e.g., costs).

5.1 Product Research and Development

Participants discussed the stages of development of specific nanotechnology applications (e.g., is the technology in the market, has it been field tested, lab tested, or in early research stages), which provided critical information for further exploration of the applications and implications of those technologies. This also informed discussion on cross-cutting issues, for instance, a technology that is already in the market may raise different governance, risk, or IP issues than a technology that is still being tested in a laboratory.

5.2 Environmental, Human Health and Safety Risks

Participants identified several areas where they felt additional environmental, health, and safety (EHS) risk research is needed. These areas included general toxicity research for nanoscale materials and products containing nanoscale materials, but also research for specific water treatment applications, including:

- Nanoparticle release and exposure risks during production and use;
- Spent waste and used cartridge disposal; and
- Nanoparticle concentrations in output water.

Participants identified a need for life-cycle assessments of nanoscale materials and products incorporating nanoscale materials. Participants also identified a need to create incentives to generate the necessary toxicological research.

Issues related to assessing and managing EHS risks are closely linked to governance issues; additional details about EHS are included below in the Governance section.

5.3 Socio-Economic Issues

Some participants expressed concern that nanotechnology applications discussed may make individuals and communities in developing countries dependent on technology suppliers. Other participants indicated that some nanotechnology applications could be locally produced from local materials thereby avoiding dependency.

5.4 Ethics

Participants discussed the ethical tension between conducting research to provide communities lacking water with as many options as possible to produce clean water and ensuring that the research being conducted does not pose significant environmental, health, safety, and other risks. Participants posed the question of whether it is ethical to continue developing specific nanotechnology applications when there are unanswered questions about the environmental, health, or safety impacts of the application.

Several participants believed that the role of scientists is to generate and provide as much information as possible about both the benefits and risks of a given line of research, and that not doing so would deny the public with high quality knowledge on which to base decisions. They also said that the large cost of having to discontinue a project due to undisclosed risks is significant enough to discourage unethical behavior.

Participants noted the tensions between various drivers and incentives. For example, research funding may require that a project produce a product that can be commercialized, while there is insufficient funding to research environmental, health, and other risks of the product. Some indicated that some scientists do not publicize information about the risks of their research to the same degree that they publicize the benefits.

In regard to products that incorporate nanotechnology, the issue of social marketing led some participants to ask whether or not information should be provided to consumers that nanomaterials were used in the product.

5.5 Intellectual Property Rights (IPRs) and Access

Participants discussed several concerns related to IPRs and the impact of patents and business strategies on the ability of developing countries to access new technologies. Participants discussed the potential for broad nanotechnology patents on conventional and natural materials at the nanoscale, and the possibility that such patents could give patent owners excessive control over the use of nanoscale materials.

Some participants pointed to the consolidation in the water industry and controversies over the privatization of water in some regions. They felt that the combination of consolidation in the industry and the potentially greater concentration of control over nanotechnologies could have far-reaching implications, including limitations on developing countries’ ability to access new technologies.
Another element of a technology assessment system could be the contaminants that can be used as manufacturing feedstocks. Using magnetic nanoparticles to clean up oil spills or reclaim applications of nanoscience and nanotechnology. These technology assessment systems could help identify opportunities for applying some technologies up-stream to treat water quality and environmental problems. For example, participants discussed the possibility of using hydrotalcite clay to reduce leaching of fertilizers into ground and surface water; and the possibility of using magnetic nanoparticles to clean up oil spills or reclaim contaminants that can be used as manufacturing feedstocks.

These technology assessment systems could help identify opportunities for applying some technologies up-stream to treat water quality and environmental problems. For example, participants discussed the possibility of using hydrotalcite clay to reduce leaching of fertilizers into ground and surface water; and the possibility of using magnetic nanoparticles to clean up oil spills or reclaim contaminants that can be used as manufacturing feedstocks.

Another element of a technology assessment system could be the determination of specific water uses and the corresponding water quality standards. Some participants felt that certain water uses (e.g., bathing or irrigation) may not require that water meets the highest quality standards, and that lower-cost treatment methods could suffice to treat the water.

5.7 Governance
Participants discussed the adequacy of existing systems for governance of nanotechnology, regulatory approaches for nanotechnology governance, including voluntary reporting programs, and alternatives to regulatory approaches such as third party certification.

Discussions about governance highlighted the need for a clear definition of nanotechnology and a framework that categorizes the classes of nanotechnology products based on their characteristics. Many participants expressed the view that different governance approaches may be appropriate for different nanotechnology applications depending on their characteristics. Some people, for example, expressed the view that technologies with nanoscale pores, such as nanofiltration membranes, may not pose the same opportunities and risks as technologies that involve loose nanoscale particles, systems of nanoscale particles, or other advanced applications of nanoscience and nanotechnology.

5.8 Capacity Building
Developing countries need educated and trained staff and access to information to evaluate technologies and choose the best available option(s) to meet their near-term needs. There may also be a need for longer-term research and development to improve existing technologies or develop new technologies to better meet existing needs.

Participants emphasized the importance of capacity-building to ensure that any technology adoption is sustainable. Several participants suggested that capacity-building should consist of:

- Empowering people to identify what their needs are;
- Providing access to information to assess the benefits and risks of specific technologies and select technologies that are most appropriate for them; and
- Building capacity for local production and control of the technology.

Many of the participants suggested that an underlying requirement for effectively addressing the various cross-cutting issues is trust, including trust in governance structures, academic and industry researchers, risk assessment methods, government and third-party safety standards for both contaminant levels and nanoscale materials, and the contributions and motives of all other stakeholders.
government agencies charged with building capacity and sharing information with local communities are sufficiently equipped to carry out their tasks.

5.9 International Collaboration and Cooperation
As described in the “Next Steps” section, participants identified specific opportunities for international collaboration and cooperation related to addressing specific opportunities and risks related to nanotechnology applications for water and sanitation.

5.10 Scalability, Delivery, and Sustainability
Participants discussed issues that might differentiate conventional technologies and nanotechnologies, especially when viewed from an international development perspective, in regard to issues of scalability, delivery, and sustainability. In general, both conventional and nanotechnologies require strong local partners for distribution and adoption. Some participants felt that nanotechnologies that can be manufactured locally with local resources may make supply chains and manufacturing infrastructure less important compared to conventional technologies. Examples of nanotechnologies with these characteristics were discussed during the workshop (e.g., clay “teabags” and magnetic nanoparticle filters).

Several participants noted that issues related to scalability, delivery, and sustainability are closely linked with costs. They noted, therefore, the important connections between water and energy. For example, desalination and filtration is often cost prohibitive due to the energy required to pressurize the treatment systems. If technological advances lead to cheap, reliable and accessible energy sources, this could lead to cost-effective and sustainable approaches for improving people’s access to safe drinking water.

* http://www.merid.org/nano
Throughout the meeting in both plenary and workgroup sessions, participants discussed specific nanotechnology applications potentially relevant to water supply and sanitation challenges in developing countries. These discussions were initiated by participants familiar with specific nanotechnologies (in many cases, by individuals directly involved with the development of the nanotechnologies being discussed). Participants explored specific applications within the following classes of technologies (see “Matrix of Technologies and Cross-Cutting Issues” section):

- Nanofiltration membranes;
- Nanoclays;
- Nanocatalysts;
- Magnetic nanoparticles; and
- Nanosensors.

The examples were not meant to be indicative of the full range of nano-based water treatment methods and devices available or in development, but were intended primarily as illustrative examples of the differences in the types of devices that may fall under each category of nano-based treatment technologies. Additional examples of technologies representative of each category are described in the “Overview and Comparison of Conventional and Nano-Based Water Treatment Technologies.”

6.1 Nanofiltration Membranes

Nanofiltration is the latest step in the technical evolution in water filtration. Technologies including sand filtration, microfiltration, and ultrafiltration have provided increasingly effective methods for removing turbidity and microbes but are generally ineffective for removing dissolved compounds. Reverse osmosis (RO) enables the removal of dissolved salts but uses conventional filtration membranes that require the application of pressure to force water through, making it energy intensive and higher in operating costs. Nanofiltration effectively removes a range of contaminants, including dissolved salts and other chemicals such as nitrates, chloride, calcium, and magnesium, using nanoporous membranes that are more permeable and selective than conventional membranes and, therefore, require less pressure and, subsequently, less energy.

Nanofiltration and nanofiltration membranes have been used for several decades, but continuing advances in the ability to manipulate materials at the nanoscale are opening new design and deployment opportunities for this technology. Most nanofiltration membranes that have been available for several years are made of bulk scale solid materials, such as carbon, silicon, polymers or ceramics, with naturally-occurring or etched nanoscale pores. Newer nanofiltration membranes are manufactured with new nanostructured materials and/or nanocomposites of polymer and inorganic materials that allow for control over the materials’ pore size, selectivity, and other physical characteristics, as well as the chemical processes that occur within the pores upon contact with contaminants.

The effectiveness of all filtration methods is dependent on the quality of the source water; the nature of the contamination, and the desired water quality standards. Different types of membranes are appropriate for different contaminants. Newer nanofiltration membranes with customized physical and chemical properties are, therefore, a significant advancement towards meeting the need for targeted contaminant removal.

Filmtec Nanofiltration Plant (Malutsa, South Africa)

Participants discussed several examples of nanofiltration, but focused primarily on the nanofiltration approach described in the South African case study described in the background paper “Nanotechnology, Water, and Development.” In this case study a small rural community used a simple water treatment plant incorporating nanofiltration membranes that are commercially available from Filmtec (Filmtec CTCI and NF270 filters) to treat polluted groundwater. The filtration membranes, which are made of a ceramic material with nanoscale pores, were successively connected to a simple, compact, and readily transportable community-scale nanofiltration plant called a cross-flow reactor that consists of a high-pressure pump that moves water from a 10,000 liter feed water tank through two cartridge filters and the nanofiltration membranes and into a 10,000 liter product water tank. The water treatment system was designed by the South African company Malutsa, which also provides technical assistance on demand and training for community members on routine maintenance of the device.

Long Beach Method (Long Beach, US)

Another nanofiltration example was the referred to as the Long Beach Method because it was developed by the Long Beach Water Department, a public utility in the US. The Long Beach Method uses existing nanofiltration membrane technology for desalination, but adds an innovative two staged nano-filtration process that requires much lower pressure than other desalination methods. Long Beach Water has obtained a US patent on its desalination method. This technology was not discussed in detail and is not included in the matrix below.
Nanostructured clays consist of nanosize particles and are ubiquitous in nature and are used in a variety of manufacturing processes. These clays are naturally occurring minerals with nanocrystalline structures consisting of two-dimensional nanoscale crystal lattices. They exhibit very high surface areas and cationic exchange properties, making them suitable for a variety of adsorption applications such as removing oil, heavy metals, and organic compounds from water and wastewater. These clays can be acquired and purified inexpensively and modified to exhibit specific functionalities through ion exchange, metal impregnation, and other simple procedures. For example, naturally hydrophilic nanoclay can be rendered organophillic (attracting organic and oily substances while rejecting water) through an ion-exchange reaction with an organic compound such as alkyl ammonium.

Though nanoclays are widely used by industry for treating oily wastewater, participants generally commented that these clays are underestimated materials for the treatment of drinking water. Further research into the potential uses of different types of clays could yield more clay-based water treatment methods and lead to them being more widely used.

Hydrotalcite (CSIRO, Australia)
CSIRO in Australia has developed a process that enables low-cost, local production of synthetic anionic clay called hydrotalcite that can...
be used to remove arsenic and possibly fluorides from water. Hydrotalcite, which is currently used in a variety of applications including antacids and time-release fertilizers, is synthesized by combining an ammonia solution with a mixed solution of magnesium or aluminum. The magnesium and aluminum solutions are both prepared with commonly occurring materials called magnesite and bauxite. CSIRO’s process can salvage magnesium from bittens (a by-product from the production of table salt) using seawater and aluminum cans, reducing production costs and enabling local production.

The production process can be scaled up or down and can be carried out in small plants or incorporated into nitrogenous fertilizer plants due to a similarity in production process. The natural color of hydrotalcite is white, which through some very preliminary testing appears to be more acceptable to consumers than black or brown clay.

Methods are now being developed for deploying this technology in a product aimed at low-income communities. The clay could be sprinkled on top of the water where it would sink to the bottom. Another idea is to sell the clay in teabags that are steeped in water prior to drinking and to create a system to buy back the tea bags for reprocessing and to dispose of wastes. At the community level, hydrotalcite can be installed in the form of an in-line filter in hand pumps, though such a system would require maintenance and additional costs related to incorporating the clay in a porous matrix.

<table>
<thead>
<tr>
<th>Cross-Cutting Issues</th>
<th>NANOCLAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydrotalcite (CSIRO Australia)</td>
</tr>
<tr>
<td>Product Research and Development</td>
<td>• No specific comments on this issue for this technology.</td>
</tr>
</tbody>
</table>
| Environmental, Human Health, and Safety Risks | • A participant indicated that hydrotalcite has long been used in antacids, which suggests that it is not harmful to human health or the environment.  
   • Participants raised a number of questions related to the use of hydrotalcite to remove arsenic from water.  
     – Will this use produce arsenic-rich waste streams?  
     – How do you set up a reliable system for regeneration, reuse, and safe removal of arsenic waste? The removed arsenic could be used for industrial applications such as semiconductor fabrication and paving roads.  
   • Participants also commented on the idea of distributing hydrotalcite in “teabags” for household level water treatment (see description, above).  
     – Some participants suggested used teabags have value and could be sold back to the supplier to be rejuvenated and reused.  
     – Will teabag regeneration and reuse pose arsenic exposure and release risks? One participant noted that because the contaminants are bound within the clay, there is no risk of dermal exposure. Another participant noted that health risks associated with arsenic stem from chronic exposure.  
   • Some participants suggested that more environmental and human health impact studies be conducted by an independent entity. Participants raised questions about who should conduct these studies and with what oversight. |
| Socio-Economic Issues                  | • Some participants commented on the idea that hydrotalcite might be used to address problems resulting from inappropriate and/or excessive use of fertilizers. They suggested that the source of the problem – overuse or inappropriate use of fertilizers – should also be addressed. |
| Intellectual Property Rights and Access | • CSIRO owns a patent on the hydrotalcite manufacturing process. As a public institution, CSIRO has a humanitarian use licensing policy. |
| Public Participation and Engagement    | • See comments above in “Socio-Economic Issues” |
| Governance                             | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Capacity Building                      | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| International Collaboration and Cooperation | • See Next Steps section for details related to collaboration and cooperation. |
| Scalability, Delivery, and Sustainability | • Sud-Chemie produces a hydrotalcite magnesium-aluminum (bauxite) for US$1,000 per ton. CSIRO has developed a very cheap method to produce this material using readily available materials (e.g., soda cans and ocean water).  
   • CSIRO’s production process is very easy, low-cost, and scalable. The product could easily be produced locally by communities in developing countries. Sustainability of a project to produce hydrotalcite in developing country communities depends on access to supplies.  
   • The technology developers have found it challenging to find people interested in developing a product aimed at low-income communities. Some participants suggested that NGOs working on arsenic issues and who have experience with technology development (e.g., IDE Bangladesh) might be well positioned to help develop a product that would be acceptable to local communities. Some participants suggested the need for a proof of concept to demonstrate the benefits and limitations of the technology.  
   • A participant suggested that studies should be conducted to assess whether the technology could be licensed and commercialized.  
   • Participants discussed whether governments should be pressured to an active interest in disseminating the technology if everything is in place to apply the technology responsibly.  
   • Some participants suggested that social and economic studies should be conducted to determine an effective strategy for buying back used teabags (if the approach is taken to sell hydrotalcite for household water treatment in teabags).  
   • They also suggested that social marketing studies should be conducted on the acceptability of using white clay versus brown or black clay. |
6.3 Nanocatalysts
A catalyst is a substance that promotes the chemical reaction of other materials without becoming permanently involved in the reaction. Nanocatalysts include enzymes, metals, and other materials with enhanced catalytic capabilities that derive from either their nanoscale dimensions or from nanoscale structural modifications. Controlling a material’s size and/or structure at the nanoscale can produce catalysts that are more reactive, more selective, and longer lasting. Consequently, smaller quantities of catalysts are needed, reducing raw material consumption, byproducts and waste, and, potentially, the overall cost of catalysis.

Several technologies were described during the Water Workshop that use the chemical reactivity of nanoparticles, including their electronic structure, surface charge, and surface area, to catalyze chemical reactions that result in the removal of contaminants from water.

Nanoparticle Filter (Indian Institute of Technology and Eureka Forbes, India)
A participant from the Indian Institute of Technology in Chennai, India described a filter containing metal nanoparticles designed to catalyze chemical reactions to remove pesticides and other organic contaminants, such as DDT, endosulfan, malathion, and chlorpyrifos from water. The filter consists of a porous ceramic or polymer membrane embedded with copper, gold, and/or silver nanoparticles. The technology has been licensed to Eureka Forbes in India, which is taking the filters into production.

Carbon Nanotube-based Photocatalysis (Monad Nanotech, India)
Another participant described a technology that uses the natural photocatalytic properties of carbon nanotubes and ferric oxide to eliminate micro-pathogens (e.g., E. Coli) and other organic contaminants from water. This technology can use any visible light, not just sunlight, to catalyze a reaction, making it functional across a broader light spectrum than other photocatalysts such as titanium dioxide. This technology, which is currently at the laboratory stage of development, has undergone laboratory tests in which carbon nanotubes were added to water to be treated, though the intent is to ultimately embed the particles in a matrix. For instance, the carbon nanotubes could be incorporated into candle or column filters through which water flows for use at household or multi-household level. This technology will likely have to be combined with other technologies in order to produce safe drinking water, because it does not address water color and may be ineffective for excessively turbid water.

Nanoscale Zero-Valent Iron (PARS Environmental Inc., US)
PARS Environmental, an environmental engineering firm in the US, manufactures zero-valent iron used for in situ remediation of microbial and organic (VOC) contamination in groundwater. Participants briefly described the use of nano-scale zero-valent iron (NZVI) for in situ remediation of contaminated groundwater, a technology that has been approved and field-tested by the US Environmental Protection Agency (EPA) for the remediation of a so-called Superfund site that is highly contaminated with Trichloroethylene (TCE). NZVI functions simultaneously as an adsorbent and a reducing agent, causing organic contaminants to break down into less toxic simple carbon compounds and heavy metals to agglomerate and stick to the soil surface. NZVI can be injected directly into the source of contaminated groundwater for in situ treatment or embedded in membranes for ex situ applications. Once released in the environment, the NZVI cannot be removed, though their consumption during reactions with contaminants and relatively low mobility may reduce the risk of environmental impacts. This technology was not discussed in detail and is, therefore, not included in the matrix on page 16.

<table>
<thead>
<tr>
<th>Cross-Cutting Issues</th>
<th>Nanoparticle Filter (Indian Institute of Technology and Eureka Forbes)</th>
<th>Carbon Nanotube-based Photocatalysis (Monad Nanotech)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Research and Development</td>
<td>• No specific comments on this issue for this technology.</td>
<td>• Participants discussed the need for additional research to identify other technologies with which carbon nanotube-based photocatalysis could be combined to produce clean water in areas with highly turbid and pathogenically-contaminated water.</td>
</tr>
</tbody>
</table>
| Environmental, Human Health, and Safety Risks | • Laboratory studies have determined that the filter is effective for removing the contaminants of concern, in particular pesticides.  
• Laboratory studies by certified third party labs demonstrated that no nanoparticles were found in the filtered water at the limits of detection of existing testing systems and current standards.  
• Participants asked how the spent cartridges will be disposed.
• Participants asked whether this technology should be applied up-stream and not just at the point of use of drinking water; for example, to prevent people bathing in pesticide contaminated water. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Socio-Economic Issues                | • Participants asked whether this technology should be applied up-stream and not just at the point of use of drinking water; for example, to prevent people bathing in pesticide contaminated water. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Ethics                               | • Some participants asked whether, given the potential benefits that would accrue to human health due to the successful removal of pesticides from contaminated groundwater, applications such as this be should pursued or whether regulatory frameworks should be set up first. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Intellectual Property Rights and Access | • The technology was patented by IIT and licensed to Eureka Forbes. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Public Participation and Engagement  | • Questions were raised about whether the communities and households that will receive these filters were provided an opportunity to learn about the devices and to choose whether they wish to make use of them above and beyond whatever “social marketing” was undertaken. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Governance                           | • No specific comments on this issue for this technology; see cross-cutting comments in section above and comments directly above regarding EHS risks and Ethics. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| Capacity Building                    | • No specific comments on this issue for this technology; see cross-cutting comments in section above. | • No specific comments on this issue for this technology; see cross-cutting comments in section above. |
| International Collaboration and Cooperation | • See Next Steps section for details related to collaboration and cooperation. | • See Next Steps section for details related to collaboration and cooperation. |
| Scalability, Delivery, and Sustainability | • A factory is currently under development that will produce 40,000 filters per month.  
• These filters have undergone accelerated testing and have been determined to produce enough drinking water for a household for one year, approximately 5,000 liters.  
• The company producing these filters is developing a video to explain use of the technology;  
• The filter is gravity driven and does not require power;  
• The filters will cost US$2.90 and the nanomaterial costs US$0.67.  
• The filter cartridge needs to be replaced once a year; The company producing the filters will replace the filter cartridge as part of its contract with users.  
• Participants discussed this technology as an example of the potential of public-private partnerships to develop and deploy such technologies. In conjunction, they discussed the need for an NGO partner to distribute and facilitate the use of the technology and the need for social marketing. | • It is unclear whether this process will be scaleable for the production of both household scale and village scale products.  
• Participants questioned whether this method provides a comparative advantage over simpler conventional technologies such as solar disinfection (SODIS).  
• This technology is cheaper and more efficient than titanium dioxide photocatalysts, which have a more limited light spectrum. |

*Information obtained by Meridian Institute after the workshop indicates that: 1) the filter cartridges will be in the field for a year and replaced, as part of the sales agreement, by Eureka Forbes’ local service units; 2) plastics and the useful metals from the used cartridges will be recycled; 3) the remaining balance of material will be incinerated; material remaining from incineration will be landfilled or used as filler (e.g., in brick manufacturing).
6.4 Magnetic Nanoparticles

Magnetic nanoparticles are being investigated for a variety of chemical separation applications including water treatment because they have high surface areas and can bind with chemicals without the use of auxiliary adsorbent materials. Additionally, the application of surface coatings can functionalize the chemical reactivity of magnetic nanoparticles, making them suitable as nanocatalysts for the chemical decomposition of chemicals. Once adsorption or catalysis has occurred, the magnetic nanoparticles can be removed from the water using a magnet or a magnetic field and reused.

Magnetic nanoparticles can be deployed either as “circulating” or loose particle suspended in water or as particles embedded in a “fixed bed” of clay, polymer, or other substrate material. Circulating magnetic nanoparticles can be dispersed in water where they would bind to the target pollutant and can then be recovered via magnetic separations. Fixed bed magnetic nanoparticles are embedded, for instance in filters where they would bind to the target pollutant as the water flows through the filter.

**Circulating Magnetic Nanoparticles (Rice University, US)**
The first technology discussed is being developed at Rice University in the US and involves circulating loose magnetic nanoparticles in contaminated water to bind with contaminants such as arsenic, and then removing the magnetic nanoparticles and the attached arsenic from the water using a magnetized filter. This technology is currently in the laboratory stage of development, and manufacturing methods are still being studied.

**Magnetic Nanoparticles in Fixed Bed (Tata Chemicals, India)**
The second technology consists of magnetic nanoparticles that are embedded in candle filters pursued by Tata Chemicals in India. The manufacturing costs of these filters are expected to be less than currently available and comparable technologies. Additionally, the filter material could be made using locally available materials.

**Magnetic Nanoparticles (University of Brasilia, Brazil)**
A third technology described was developed by the University of Brasilia in Brazil. The technology consists of magnetic nanoparticles designed to absorb and remove oil from water. The technology can be used to magnetize clay to separate oil, for example in case of oil spills. The clay can then be collected using a magnet. Reversing the magnetic charge allows both the clay and the oil to be reused, although the clay will eventually become less effective as it gets clogged and loses its porosity. The technology has been tested in the lab and seems promising for magnetic separation of contaminants and nanoparticles, and could be promising in combination with other clays for specific applications because of its “tune ability,” affinity, and reactivity. The technology can also be used as “tags” to magnetize yeast cells to metabolize dyes in wastewater from textile plants. It is expected that the magnetic nanoparticles can also be used to magnetize other bacteria for treating additional contaminants. The technology has been patented by the University of Brasilia. The cross-cutting implications of this technology were not discussed in detail and are, therefore, not included in the matrix below.
### Cross-Cutting Issues

<table>
<thead>
<tr>
<th>MAGNETIC NANOPARTICLES</th>
<th>Circulating Magnetic Nanoparticles Developed at Rice University</th>
<th>Magnetic Nanoparticles Embedded in Filter under Development by Tata Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Research and Development</strong></td>
<td>• Participants discussed the need for specific locations (i.e., communities or “test beds”) willing to work with the researchers during the technology development process.</td>
<td>• The product is being developed but is not yet on the market.</td>
</tr>
<tr>
<td><strong>Environmental, Human Health, and Safety Risks</strong></td>
<td>• The waste stream quantity is expected to be relatively low, but the concentration of potential contaminants in the waste stream could potentially be high. • Participants discussed the need for additional toxicology research on magnetic nanoparticles, as well as possible incentives that could be created to generate such research. • Benefits of the technology include that it treats contamination with arsenic 3, which is very difficult to remove from groundwater, and arsenic 5.</td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
</tr>
<tr>
<td><strong>Socio-Economic Issues</strong></td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
</tr>
<tr>
<td><strong>Ethics</strong></td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
</tr>
<tr>
<td><strong>Intellectual Property Rights and Access</strong></td>
<td>• Not yet patented; may be patented by Rice University.</td>
<td>• Developed by Tata Chemicals</td>
</tr>
<tr>
<td><strong>Public Participation and Engagement</strong></td>
<td>• See Product Research and Development immediately above.</td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
</tr>
<tr>
<td><strong>Governance</strong></td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
</tr>
<tr>
<td><strong>Capacity Building</strong></td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
<td>• No specific comments on this issue for this technology; see cross-cutting comments in section above.</td>
</tr>
<tr>
<td><strong>International Collaboration and Cooperation</strong></td>
<td>• Participants offered to work with Rice University to “test bed” the technologies in India and Africa.</td>
<td>• Participants discussed the need for collaborative partners to help further develop and distribute candle filters embedded with magnetic nanoparticles. • Several participants offered to collaborate with Tata to explore development and distribution of their product. • Production is scalable from micro to small to medium to large.</td>
</tr>
<tr>
<td><strong>Scalability, Delivery, and Sustainability</strong></td>
<td>• The scalability of the technology has not yet been determined, though it is likely that it is most suitable for point-of-use applications. • A manufacturing process has yet to be developed; it is unclear whether the product could be locally manufactured. • The technology would be relatively cheap (US$10 - US$100 range), and does not require power. • It is expected that the product could be made available for distribution in the next 24 to 36 months.</td>
<td>• The filter material could be made by individuals using locally available materials (e.g., sand and rice husks). • Using the technology does not require power. • The manufacturer plans to make the product freely available. Some participants suggested selling it at low cost to improve chances of adoption. • Manufacturing costs are 1/20th of costs of currently available and comparable technologies.</td>
</tr>
</tbody>
</table>
6.5 Nanosensors
Participants provided brief descriptions of several types of nano-based sensors for detecting contaminants in water. These included simple sensors that provide a color-metric indication of the presence of a contaminant, and more sophisticated sensors that provide electronic readouts of contaminant levels or detect multiple contaminants at one time. Color-metric nanosensors were described as the most developed type of nanosensor. They are easy to use but they are unable to provide quantitative information about contaminant levels or to detect low concentrations of contaminants. Therefore, they may produce a high number of false-positive readings.

Participants discussed the value of improving access to water quality data in developing countries. Some participants felt that nanosensors would empower communities by giving them the ability to detect contaminants and use the information to hold polluters accountable or to pressure the government to clean the water supply. Some participants felt that knowledge of contaminants can help communities monitor water-borne illnesses or to test whether the output water from treatment devices is uncontaminated, which may be a concern for devices that require frequent filter changes. Other participants felt that knowledge about water quality may not be very helpful to communities that do not have alternative, clean water sources. In that case, the information (and nanosensor technology providing the information) might actually be disempowering. Some participants said that methods for detecting contaminants are already available, but the real problem is there are not enough test sites to compensate for the high instances of false positive and false negative readings, and that monitoring is very time-consuming.

Given the prevalence and increasing use of bottled water throughout the world, participants discussed the likelihood that color-metric nanosensors will be incorporated into water bottles and used to make claims about the quality of the water within the container. Some participants expressed concerns about whether the sensors will be designed to test for the right set of potential contaminants and the degree to which they may give a false sense of security if they do not. Some participants suggested that potentially challenging ethical and liability issues may arise for corporations that pursue this technology.
Next Steps

Participants identified follow-up actions and activities ranging from technology-specific to national and international in scope, including:

- Developing and disseminating more robust general information about nanotechnology, water, and development through publications and websites.
- Improving resources for helping people compare nanotechnology-based and conventional products for improving sanitation and access to clean water.
- Addressing cross-cutting issues in the context of specific technologies.
- Developing broader networks of people interested in these issues, in part through utilization of information technology tools.
- Organizing additional workshops on topics pertinent to nanotechnology and development (e.g., commodities, nanotechnology and development and water, nanotechnology and development).
- Exploring nanotechnology governance, especially those issues of most significance and interest to developing countries.

Several individuals expressed an interest in following up on specific ideas. Next steps identified during the meeting are summarized below.

More Robust Information about Nanotechnology, Water and Development

- Water Workshop Website
  Meridian Institute will develop a website where resources related to the Water Workshop will be made available. The website will include all the workshop materials, the workshop summary, pictures, and discussions forums. The discussion forums will provide on-line tools where participants and others interested in the topics from the workshop can share progress reports, comments, and ideas related to issues discussed during the workshop.

- Region-Specific Resource Portals
  Meridian Institute and The Energy and Resources Institute (TERI) are exploring a collaborative effort to make a more robust set of information about nanotechnology in India available through a web portal that builds on the Meridian Nanotechnology and Development News (NDN) service. The Portal would enhance coverage of nanotechnology developments in India through NDN’s daily news summaries, and would provide direct access to the following resources about nanotechnology developments in India:
  - NDN news summaries focused on India;
  - An archive of India-focused NDN summaries;
  - An advanced search function enabling customized searches of the archive by stakeholder group, applications, implications, or any combination of those categories;
  - A “resources” website providing links to websites of organizations involved with nanotechnology in India, which can be sorted alphabetically or by organization type (e.g. academia, government, private sector, NGO, etc.)
  - An interactive forum for users to discuss issues related to nanotechnology in India.

Meridian Institute is exploring the possibility of developing additional country and region-specific resource portals.

Resources to Facilitate Comparison of Conventional and Nanotechnology-Based Products

Participants provided very favorable feedback about Meridian’s paper, “Overview of Conventional and Nano-Based Water Treatment Technologies.” Several participants expressed a desire to build on the paper to provide a more powerful tool for helping people compare the characteristics of both conventional and nanotechnology-based water treatment applications for specific water quality problems (e.g., arsenic, pesticides, bacteria, viruses, etc.). Many participants expressed support for a document that would help people match problems with technologies. People urged that the document contain more technical and cost data, as well as information about other cross-cutting issues discussed during the workshop (e.g., IPRs, EHS risks). Collaborators on the article will explore the possibility of having such a paper peer-reviewed.

Addressing Cross-Cutting Issues in the Context of Specific Technologies

Several participants expressed interest in collaborating with other workshop participants to further explore the potential opportunities and risks associated with specific technologies discussed during the workshop.

- Assessing Technologies for Arsenic Removal
  Several technologies were discussed that provide potentially affordable and effective solutions for arsenic removal from groundwater: hydrotalcite (synthetic clay); circulating magnetic nanoparticles technology; a candle filter with embedded magnetic nanoparticles. A handful of workshop participants – people working in developing countries on arsenic problems, researchers, companies, and NGOs – agreed to work together to test and assess issues such as effectiveness, cost, safety, scalability, sustainability, and accessibility (i.e., IPRs) of new
nanotechnology-based technologies for treatment of drinking water contaminated with arsenic (and microbial contaminants).

- Tracking Developments Regarding IPRs

Some participants expressed an interest in tracking trends and developments related to IPRs and their impact on access to nanotechnologies for water treatment.

**Governance**

Several participants identified the need for more robust discussions about nanotechnology governance.

- National Nanotechnology Governance

Given that nanotechnology products are already entering the market – including products for treating contaminated water – several participants from developing countries expressed an interest in assessing the applicability of existing national regulatory frameworks for governing the use of nanoscale materials or nanotechnologies that they may be developing themselves or may be importing. These assessments would include identification of existing environmental, health, and safety (EHS) standards that apply to these nanomaterials and an assessment of the adequacy of these standards for nanoscale materials. If, as many people expect, there are gaps in existing regulatory standards, systems, and capacity regarding nanotechnology in developing countries, several participants indicated an interest in exploring potential intermediate steps to fill these gaps, such as developing voluntary guidelines and standards for risk assessment and risk management, systems to collect and share existing data about the impacts of nanoscale materials, and incentives for (funding of) environmental and health risk studies.

- International Dialogue on Nanotechnology Governance

Participants identified a need for international discussions focused on developing countries’ needs and priorities with regards to governance of nanoscale materials and nanotechnologies. Given the significance of governance issues, Meridian Institute will continue to track existing initiatives that are focusing on or include governance as part of their terms of reference and explore whether complementary processes and strategies are needed, especially processes aimed at identifying developing country priorities, exchanging expertise between developing countries, and ensuring that the perspectives of developing countries are included during (not after) deliberations by developed countries. In the interim, Meridian will ensure that sector-specific workshops, such as the International Workshop on Commodities, Nanotechnology, and Development in Brazil, will include specific discussions about governance. These discussions will enable participants to clarify what they mean by “governance” and the steps that are needed to address the nanotechnology governance deficit identified by participants.

**Additional Workshops**

The Water Workshop illustrated the benefit of sector-focused discussions (e.g., on water and sanitation). Participants agreed that further sector-specific workshops would be valuable and are a unique approach that distinguishes the GDNP from other initiatives.

- International Workshop on Nanotechnology, Commodities, and Development (Commodities Workshop)

Meridian Institute is convening a Commodities Workshop will take place in Brazil in May 2007. There is a clear link between commodities and poverty. Many developing countries are heavily dependent on commodities for employment and revenue. Recent publications suggest that some applications of nanotechnology could increase global demand, while others could lead to a decrease in demand for specific commodities. The goals of the Commodities Workshop are to: examine nanotechnology applications that are effecting or may effect demand for agricultural and mineral commodities; identify mechanisms (existing or new) to anticipate, analyze, and respond to relevant shifts in commodity markets resulting from nanotechnology applications; and catalyze actions that could proactively address potential opportunities and risks associated with shifting demand for commodities resulting from nanotechnology applications. Approximately 40 people will be invited to participate in this international workshop.

Given high interest within Brazil in the topic of nanotechnology and commodities, Meridian proposes to precede the international, multi-stakeholder workshop with a 1-day public workshop (open to the public, but seating would be limited to meeting room capacity estimated at 100 to 200 people) with presentations and discussion of nanotechnology applications potentially relevant to development, especially applications related to agriculture, minerals, and mining.

- International Workshop on Nanotechnology, Energy, and Development (Energy Workshop)

Several participants pointed at the important connections between water and energy. Meridian Institute is exploring the possibility of organizing an international workshop on nanotechnology, energy, and development, which would be modeled after the other sector-specific workshops.
The Water Workshop helped create new and unique connections between communities of people that had limited interactions in the past. These connections resulted in several important insights, summarized in this document that will inform future multi-stakeholder discussions on nanotechnology and development.

The Water Workshop confirmed the utility and power of sector-focused discussions to inform and focus dialogue on the opportunities and risks of nanotechnology for developing countries. This focused discussion was meaningful to participants because it: 1) was about a critical issue affecting millions of people in developing countries; 2) enabled people to better understand nanotechnology through discussions about specific applications to water treatment; and 3) was a powerful way of identifying and discussing non-technical, cross-cutting issues of importance.

The workshop catalyzed activities that will continue to focus on issues related to nanotechnology, water, and development, while simultaneously setting the stage for future discussions about other specific sectors (e.g., commodities and energy) and broader issues such as nanotechnology governance.

Participants identified a range of follow-up actions and activities ranging from technology-specific to national and international in scope. These included project-specific collaborations to: further explore opportunities and risks of specific technologies; generate and disseminate information to help people match technologies (nanotechnology and conventional) with specific water quality problems; and discussing nanotechnology governance issues at a national and international level. Meridian Institute is taking an active role in pursuing follow-up actions and will periodically check with participants on the progress they are making.
Annex 2: Workshop on Nanotechnology, Water, and Development Agenda

Global Dialogue on Nanotechnology and the Poor: Opportunities and Risks
Workshop on Nanotechnology, Water, and Development | Draft Agenda
10 – 12 October 2006
M.S. Swaminathan Research Foundation | Chennai, India

Meeting Objectives

Develop recommendations and identify activities that will inform decisions and catalyze actions by stakeholders (e.g., water experts, development experts, governments, NGOs, companies, universities, international institutions, donors) involved with:

- Nanotechnology research and development efforts relevant to providing clean water in developing countries.
- Activities to address potential environmental, health, safety, socio-economic, and other issues related to the use of nanotechnology in water treatment devices.

In achieving these objectives participants will discuss a range of issues including, but not limited to, the following:

- What are the barriers to improving basic sanitation and access to clean water in developing countries?
- How can science, technology, and existing knowledge help address these challenges?
- What potential does nanotechnology present to help address these challenges?
- To the extent that nanotechnology presents opportunities, are there risks and other issues that need to be addressed?
- What can be done to catalyze and accelerate activities that address these opportunities and risks?

Tuesday, 10 October 2006

09:00 Welcome, Introductions, Meeting Objectives and Agenda Review
M.S. Swaminathan Research Foundation
International Development Research Centre
International Water Management Institute
The Energy and Resources Institute
Meridian Institute

Participants will be asked during introductions to briefly comment about their interest in water issues and nanotechnology, especially implications for developing countries.

10:30 Break

11:00 Presentation – Human Development Needs Regarding Clean Water and Sanitation, Opportunities and Risks of Nanotechnology Applications for Clean Water, and Case Studies’

Presented by the co-authors of a background paper on Nanotechnology, Water, and Development:

- Yvani Deraniyagala, Munasinghe Institute for Development, Sri Lanka
- Mlhuti Hlophe, University of North West, South Africa

11:45 Plenary Discussion – Key Development Priorities and Opportunities for Applying Nanotechnology to Provide Sanitation and Clean Water in Developing Countries

Building on the presentation and background papers, participants begin to:

- Clarify key development priorities for providing sanitation and clean water in developing countries and the challenges poor communities face in improving their access to sanitation and clean water (e.g., social, economic, political, cultural, technical).
- Examine the “water issue” from a holistic, systems perspective that includes, for example, the linkage between water and sanitation and between domestic wastewater and agricultural and industrial demand for water.
- Identify specific nanotechnology applications for clean water (i.e., technologies that are on the market and those in development).

Specific questions for discussion include, but are not limited to:

- What are the barriers to improving sanitation and access to clean water in developing countries?
- How can science, technology, and existing knowledge help address these challenges?
- What potential does nanotechnology present for addressing these challenges?

13:15 Lunch

Case studies focus on projects designed to provide clean water in developing countries using both nano and non-nanotechnologies.
14:30 Plenary Discussion – Potential Environmental, Health, Safety, Socio-Economic, and Other Issues Related to the Use of Nanotechnology to Provide Clean Water in Developing Countries

- Building on the presentation and background papers, participants begin to identify potential environmental, health, safety, socio-economic, and other issues (e.g., intellectual property rights; nomenclature; public engagement and participation; capacity building; information exchange; and international collaboration and networks) related to the use of nanotechnology to provide clean water in developing countries.

Specific questions for discussion include, but are not limited to:

- To the extent that nanotechnology presents opportunities, are there risks and issues that need to be addressed?

16:00 Break

16:30 Plenary Discussion – Summary of Key Points from Day 1

17:00 Adjourn for the Day

17:30 Appetizers and Hosted Dinner

**Wednesday, 11 October 2006**

09:00 Summarize Outcomes of Day 1; Review Agenda for Day 2

09:15 Participant Reflections from Day 1

10:00 Break

10:30 Small Group Discussions – Recommendations for Catalyzing Action

Reflecting on the discussion from Day 1, participants will break into small groups to develop recommendations for catalyzing actions directed at specific opportunities and risks. For example, one group might explore how to promote opportunities and address risks associated with nanofiltration devices while another small group might do this for desalination technologies. Other small groups might address issues that cut across technologies.

Participants will be asked to address questions such as:

- What are the specific opportunities and risks that deserve attention?
- What should be done to inform decisions and catalyze actions specific to these opportunities and risks?
- Which individuals and institutions could help address these opportunities and risks?
- What role can South-South and North-South collaborations play? What role can regional and sub-regional networks play?
- What are immediate next steps?
- Are the recommended actions specific to a product, category of technology (e.g., filtration), or generic across water treatment technology categories (e.g., filtration, desalination, and catalyst)?
- Are there existing initiatives and activities that are focused on these or similar issues?

In the course of the small group discussions, participants will be encouraged to identify connections to relevant other processes and clarify connections to the broader array of GDNP activities.

12:30 Lunch

14:00 Small Group Discussions – Continued

15:00 Break

15:30 Plenary Discussion – Small Group Reports on Recommendations for Catalyzing Action

Small groups report back to the plenary about their recommendations for catalyzing action regarding opportunities and risks. The full group discusses and expands on the results of the small group discussions.

17:00 Adjourn for the Day

18:30 Hosted Dinner

**Thursday, 12 October 2006**

09:00 Summarize Outcomes of Day 2; Review Agenda for Day 3

09:15 Participant Reflections from Day 2

10:00 Plenary Discussion – Recommendations for Informing Decisions and Catalyzing Actions that Address Opportunities and Risks

Participants will develop recommendations and identify commitments they are willing to make that will help inform:

- Nanotechnology research and development efforts relevant to providing clean water in developing countries;
- Activities to address the potential environmental, health, safety, socio-economic, and other issues related to the use of nanotechnology applications for clean water;

For each recommendation, participants will be asked to comment on the following questions:

- Are these recommendations, which emanated from a discussion about nanotechnology and water treatment devices, applicable in other sectors (e.g., energy, health, agriculture)?
- What on-going role, if any, is appropriate for the GDNP beyond making recommendations?
- What are immediate next steps?

11:00 Break

11:30 Plenary Discussion – Finalize Recommendations and Commitments from Participants to Help Implement Recommendations

12:30 Closing Comments

13:00 Adjourn – Lunch
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