Access to Safe Water: Approaches for Nanotechnology Benefits to Reach the Bottom of the Pyramid

Final Technical Report

May 2011

Prepared By

TARA

Supported by

DFID Department for International Development

TARA / DA RESEARCH TEAM

Core

Dr K. Vijaya Lakshmi

Kriti Nagrath

Aditi Jha

Support

Vrinda Chopra

Dr Uzma Nadeem

Pramod Kumar

Advisors

Dr Arun Kumar

Shrashtant Patara

Dr Soumen Maity

Report citation: Vijaya Lakshmi K., Nagrath K., Jha A., 2001. Access to Safe Water: Approaches for Nanotechnology Benefits to Reach the Bottom of the Pyramid. Project report to UK DFID, May 2011. Development Alternatives Group, New Delhi.

CONTACT DETAILS

Technology and Action for Rural Advancement
B-32 Tara Crescent
Qutub Institutional Area
New Delhi – 110016, India
Tel: 91-11-2613 4103, 2689 0298
www.tara.in
www.devalt.org

Acknowledgements

This study is based on a research project funded by the UK Department for International Development under the New and Emerging Technologies research competition. We thank DFID for their support and co-operation through the duration of the study. The project was led by Technology and Action for Rural Advancement, Development Alternatives Group. We confirm that the views and errors in this document are the authors alone.

We thank Dr Praveer Asthana – Mission Director (Nano Mission), Dr Prasada Raju and Dr Sanjay Bajpai, Department of Science and Technology, Government of India, for their support and help during the workshop series, including the key note address at the Delhi Workshop in April 2011. In Mumbai, we thank Dr Dhiren Bahadur, Indian Institute of Technology – Bombay for his partnership and guidance through the workshop as well as his keen insights into the scope of nanotechnology for water purifications.

Many academic institutes, contributed to the research and provided valuable inputs the workshop, including the Indian Institute Of Sciences, Bangalore, Center For Nanomaterials And Nanotechnology - University Of Mumbai, University of Pune, Bhabha Atomic Research Centre - Mumbai, Indsearch Centre Of Sustainability Of Management - Pune, Indira Gandhi Center For Atomic Research - Kalpakkam, Bangalore University, Vellore Institute Of Technology , Indian Institute Of Chemical Technology - Hyderabad S.V.University - Tirupati, Indian Institute of Toxicology Research – Lucknow, Banaras Hindu University – Banaras, Agharkar Research Institute – Pune, the International Advanced Research Centre for Powder Metallurgy and New Materials - Hyderabad etc.

Support for the research was also widespread with engagement across the industry and civil society, including Arsenic Task Force - Government of West Bengal, TATA Chemicals, Thermax, Eureka Forbes Pvt. Limited, Aditya Birla Science & Technology Company Ltd., Filtrex, Underwriters Laboratories, Action for Food Production, India Water Partnership, Safe Water Network, The Energy and Resources Institute, World Bank, US Embassy, GRASP Analytique, etc. (Annexure – Workshop Proceedings). We thank all of them for their time and valuable insight.

For more information: Email: kvijayalakshmi@devalt.org
Website: www.devalt.org

Content

List of Figures

Executive Summary

One in eight persons in the world lack access to safe water. Over 3.5 million people die each year from water-related disease; 84 per cent are children. 98 per cent occur in the developing world. **The need to provide safe drinking water to poor people in developing countries cannot be overemphasised**. **Nanotechnology** has the potential to deliver **affordable** and **effective solutions** for water purification, providing access to safe drinking water to millions of people. This will contribute to poverty alleviation and achievement of the Millennium Development Goals (MDGs).

Nanotechnology has introduced a new generation of water filters and purification systems. Research on nano catalysts like silver, iron, titanium dioxide and Carbon nanofiltration membranes for water treatment applications is a fast growing field. Universities like Stanford, Aberdeen, Rice, etc. as well as their Indian counterparts like the Indian Institutes of Technology, Banaras Hindu University, Indian Institute of Science etc. are actively involved in nanotechnology research focused on the water technology.

Though much of this research is still at the laboratory stage, some simple, cost effective technologies incorporating nanomaterials have already reached the market, like Aquaguard Total of Eureka Forbes Limited, Swach of TATA Chemicals, etc. for point of use application targeted at both urban and rural markets. Nanotechnology offers cost effective, sustainable solutions for complex water quality problems in developing countries. While nanotechnology based water purifiers are slowly making inroads into the traditional commercial market, there exists a huge untapped market in the BoP segment.

Research suggests that materials suitably treated or impregnated with nanotechnology-based methods can filter more effectively and thereby increase the health benefits. Several researchers are testing their nanotechnology based devices in developing countries. E.g. the tea bag arsenic removal device in South Africa, Stellenbosch University, International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) testing their silver nanofilters in villages in South India. Nanotechnology offers low cost solutions as minute amounts of material are used to effectively purify water. Subsequently less waste is generated, keeping environmental impacts low.

The Department for International Development (DFID), UK; recognised that new and emerging technologies such as nanotechnology can offer huge benefits in poverty alleviation. The challenges lie in taking these technologies from the laboratory to the bottom of the pyramid (BoP). The Development Alternatives (DA) Group took up this study to understand what prevents these technologies from benefiting the masses especially with respect to providing access to safe drinking water. Phase 1 of the study adopted a two pronged approach of desk research and stakeholder consultations to identify the barriers and explore approaches that can mitigate them.

Based on the understanding built upon the literature review in the sector, the DA group initiated consultation workshops amongst a multi-stakeholder group. Representatives from the academia, industry and government were part of this series held in various parts of the country – Bengaluru, Mumbai, New Delhi. The multi-stakeholder consultations have not only served as a platform to put forth their point of view and debate the issues around nano-technology but also helped them realise the need and potential for multi-stakeholder action to ensure research benefits reach the BoP. The findings of these consultations have been widely disseminated among the participants. While the stakeholder consultations provided the supply side of the story, field studies were conducted to understand the end users perception on water quality and its purification.

During the study, it was found that nanotechnology has made huge strides in providing solutions for safe drinking water. However the widespread roll out of these solutions especially to the BoP is impeded by a few barriers. Key among them is the **lack of awareness** among the target group; first, on the status of their water resources and its **health impacts**, and second on **effective ways to address** this issue. The study found that nanotechnology research benefits can reach the BoP, through **innovative** and **appropriate delivery models**. Though the scientific community is divided about the perceived risks of nanotechnology, they are unanimous in stating that mankind should reap the benefits of nanotechnology research provided, **risks are managed** through precautionary and pro-active **policy to practice connect.** Therefore, in Phase 2 of this research the focus would be to **pilot** these **approaches** and test their **scalability potential**. The learnings from the ground will feed into developing a **regulatory framework** complemented by a set of exemplary **package of practices** for **risk management**.

The one on one meetings and multi-stakeholder consultations during the course of this study have created a great deal of enthusiasm and interest among the leading researchers, industry leaders, premier government agencies, science and technology institutions leading development practitioners and financial institutions alike. Several of them are willing to contribute and support the action research in the next phase by partnering with the DA group to pilot approaches using nanotechnology for providing safe water to the BoP. The DA group intends to take the learnings from this phase to pilot delivery models for both community based and household based systems.

Introduction

'*Remember the poor – it costs nothing'* ~ Mark Twain

- **The Context**

Today billions are spent on poverty alleviation programmes across the globe. The poor or the base of economic pyramid is characterized by their **unmet basic needs** related to food, **water**, and shelter. It is estimated that 884 million people lack access to safe water worldwide. Every 20 seconds, a child dies from a water-related disease.[1] The need for safe water cannot be overemphasised.

Various approaches have been tried out with varying degrees of success. An interdisciplinary, **multi-stakeholder approach** to dealing with **poverty alleviation** is the need of the day. Propelled by Prahalad's theory of the 'Fortune at the Bottom of the Pyramid', the market approach to poverty alleviation is gaining momentum.

Traditionally viewed as a liability, this BoP population segment of over 4 billion people is slowly emerging as an asset to the local, national and global economy. Modest estimates place the value of the BoP market at $5 trillion. In Asia the measured BoP water market is $3.2 billion (1.4 billion people); while the estimated total BoP water market in the region (including the Middle East) is $6.4 billion (2.9 billion people[2]). With an approximate population of 700 million, India's rural BoP market presents itself as a significant opportunity not only for multinational corporations but also for small and medium manufacturers and producers[3].

In order to tap this market and meet the demands of the BoP, there is a need to innovate both in terms of products and delivery mechanisms. Technology has a major role to play in this space. The DFID Research Strategy 2008 – 2013 recognised a **key role** for **new and emerging cutting edge technologies** - being developed, albeit for industrialised markets - in meeting the needs of poor people. Given the **water crisis** faced by the world today, it further noted that research was needed into the most effective, safe and affordable **approaches** to applying these new technologies in developing country situations and to ensuring the benefits are derived by the poorest.

---

[1] Water Facts, water.org
[2] Hammond A. et al, 2007, 'The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid', Worlds Resources Institute.
[3] Shukla S. et el., 2011. 'The Base of Pyramid distribution challenge: Evaluating alternate distribution models of energy products for rural Base of Pyramid in India' Institute for Financial and Marketing Research

The Development Alternatives Group, though this study, sought to identify the key challenges and barriers that reduce the **impact of nanotechnologies for providing safe water** to the **under privileged** in developing countries, its possible **environmental implications** and **remedial measures**.

Based on the understanding built upon the literature review on nanotechnologies and their application to multiple water problems, the DA group initiated consultation workshops amongst a multi-stakeholder group. Representatives from the academia, industry and government were part of this series held in various parts of the country – Bengaluru, Mumbai, New Delhi. The consultations served as a platform to put forth their point of view and also, it has established the need for cross stakeholder action networks to ensure research benefits reach the BoP. While the stakeholder consultations provided the supply side of the story, a field survey was carried out to understand the end users perception on water quality and the demand for safe water. The report presents the consolidated findings of these activities.

- **The Report Structure**

The report is structured into four themes. The first theme reflects on the **potential** nanotechnology has to offer to water purification, keeping a focus on the BoP populations. There is a vast amount of research being carried out in India and abroad on the application of various nanomaterials including metal oxides, noble metals, magnetic particles, carbon nanotubes etc. for water purification. A few technologies harnessing the antimicrobial properties of silver nanoparticles have also been marketed in India, catering to both the BoP (starting at £ 9) and higher income groups (at £ 130).

While the potential of the application of nanotechnology is apparent, the roll out is not very widespread. The second theme highlights the **barriers** that impede the realization of the potential. The sector is plagued by both supply end barriers of costs, logistics and risk management as well as demand side issues related to the awareness levels and the (felt and latent) needs of the community.

There is a need to explore successful service delivery models and absorptive capacities of the population to overcome these barriers. The next theme touches upon **emerging approaches** that have found varied degrees of success in reaching the BoP from different sectors like water, energy, ICT etc. **Design elements** which run common in these approaches as well as validated through consultations are culled out and presented.

Finally the report brings out the key **research gaps** that need to be filled in order to ensure that technology benefits reach the BoP. Incubation support and funding are impediments for productizing a proven technology. The policy environment also needs to consider risks and benefits of these technologies and be moulded so as to protect the end user and the environment. Finally the delivery mechanisms that will reach the BoP need to be explored. While we have pointers towards creating a mechanism that works, there is a need to test its' potential to be scaled up.

The study reiterated the need for in-depth translational research in ensuring that the basic needs of the BoP are met. It is time for research to move away from being a stand alone activity to work with diverse stakeholders in the field to solve real issues. Summarizing with a few key thoughts shared in the consultations, **the need of the hour is to work with the BoP and not experiment on them**. These basic needs of this population should have been met 50 years back, but we have not been able to do so. Now we should deliver but not make guinea pigs out of them.

Potential of Nanotechnology for Safe Water

Scope for Nanotechnology to Address Safe Water

The availability and access to safe drinking water, especially amongst the poor is an issue that is accelerating with time. Many water sources are contaminated with both **biological and chemical pollutants** such as arsenic, fluoride, etc. New problems like **organic contamination** (pesticides) and **increasing salinity** are affecting water sources extensively (Figure 2). Bacterial contamination in surface water and at points of use is a major reason of concern. Over 21 per cent of India's diseases are water related and one in four children worldwide who die before the age of five die of water related diseases[5]. In spite of such alarming statistics, water treatment is not practiced by majority (73 per cent - Figure 1) of the people, as seen in our field survey across North India. Besides the myriad contaminants that make water unsafe, the per capita availability of water amongst the poor in the country, even in urban areas, is very low. Thus, there is an urgent need to address the issue of safe water among the BoP.

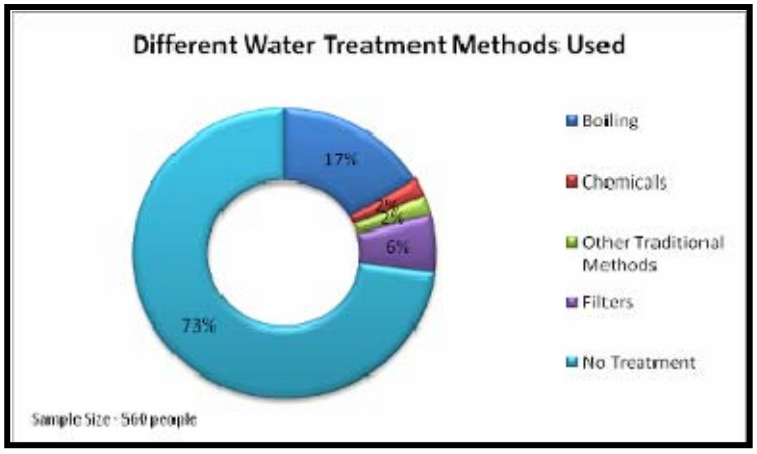

Figure 1 : Different treatment methods adopted by sample

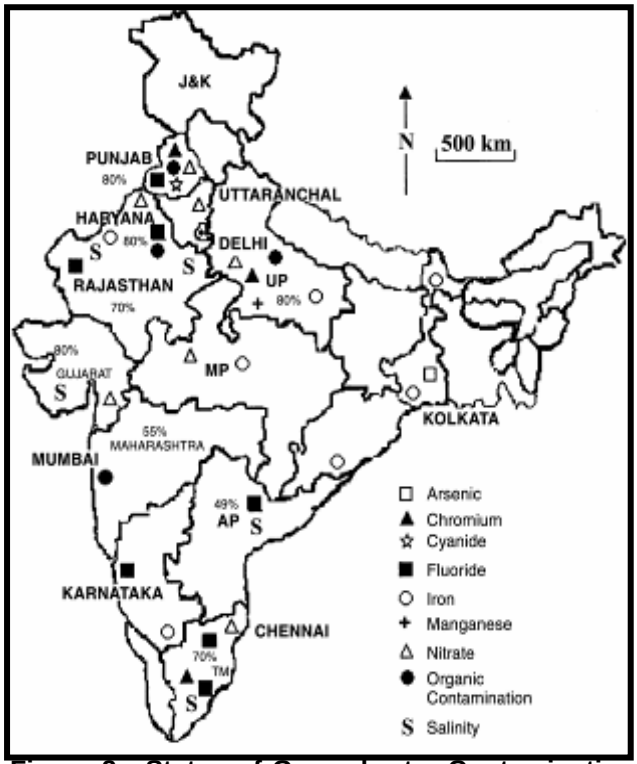

Figure 2 : Status of Groundwater Contamination in India[4]

[4] Chaudhary V. Jacks G. Gustafsson J. 2002. 'An analysis of groundwater vulnerability and water policy reform in India', Environmental Management and Health, Vol. 13 Iss: 2, pp.175 - 193

[5] De Normandie J. and Sunita J. 2002 'Combating diarrheal disease in India through safe drinking water' World Health Organisation (WHO)

Nanotechnology, the application of nano structures (between 0.1-100 nm) and principles behind them to make nano scale devices and to produce new materials, is emerging rapidly and already has a wide application in commercial products such as cosmetics, house hold appliances and paints. Nanotechnologies can provide solutions to alleviate water problems, both in terms of detection and removal of contaminants. Also since small amounts of nonmaterial are used for purification, costs and waste generation are low, providing an effective and affordable water treatment solution to the poor.

Most conventional and popular methods of water purification seem to be ineffective while addressing complex water quality problems. E.g. there is no simple conventional technology that takes care of multiple water quality problems such as bacterial and heavy metal contamination together or Heavy metals, turbidity, pesticides and salinity together. The potential of nanotechnology based methods for water purification can be seen through the four functional categories of Nanomaterials as mentioned below.

- **Nanoparticles as antimicrobial agents for water disinfection, used for killing of disease causing bacteria, viruses and protozoa.**
- **Nanomaterials as catalysts, used for removal of pesticides and other organic matter including toxins**
- **Nanomaterials as sorbents, used for the removal of heavy metals and inorganic contaminants**
- **Nanomaterials as filtering agents, used for removal of contamination by filtration**

○ Nanotechnology Scenario – Affordable and Appropriate Technologies

Great strides have been made in applying nanotechnology in varying degrees of complexity in several fields – from space travel to cosmetics. Nanotechnology for Safe water is an area that is being looked at globally and is also a priority concern in India. While there are several types of nanotechnology that are relevant to addressing safe water, there are some that may be more appropriate, affordable and sustainable for use among the BoP.

- **Global Innovations**

Simple and innovative solutions using nanotechnology have been developed around the globe. Examples are a sachet that can be fitted in the neck of a bottle containing ultra- thin nanoscale fibres which filter out contaminants plus active carbon granules which kill bacteria developed in South Africa and a 'teabag' that can be dipped into household water supplies for about 15 minutes before drinking that contains a low cost synthetic clay – Hydrotalcite; that attracts arsenic removing it from water developed by Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO). In terms of detection too, The National Nanotechnology Laboratory Applied to Agribusiness, housed at Embrapa's agricultural instrumentation unit in São Paulo, Brazil has developed a cheap optical sensor incorporating nano assembled films to evaluate the acidity of natural water supplies and 'electronic tongues' - another kind of polymer sensor that can be used to distinguish between different mineral waters and between pure water and water contaminated by organic matter.

- **National Scenario**

In India, Nanotechnology is predominantly at the laboratory stage; however some systems for water purification are at the development stage, whereas some have reached the market. Brands such as Kenstar, Philips, Thermax, TATA and Eureka Forbes all have products in the market that apply some form of nanotechnology.

Through discussions with stakeholders, the application of nanotechnology was found more feasible for personal water treatment systems at this stage although the viability of nanotechnology in community water systems is an aspect that requires further study. Our survey threw up that on an average, people are prepared to pay between ` 447 – 573 (£ 6 -8) for a purifier.

In the country, the use of silver nanoparticles for purification is the most popular due to its anti-bacterial properties. Additionally, silverware has been used for centuries by the wealthy in India to drink water; this factor could make it simpler to demystify the technology and increase demand.

From the stakeholder consultations, good examples of settlement of Intellectual Property Rights issues between research institutes and industries came up, where the former had rights to the technology and the latter had rights to the product e,g. IIT Chennai (technology) and Eureka Forbes (product), ARCI (technology) and SBP

Aquatech Pvt. Ltd. (product). This reflects positively on the potential for these two significant stakeholders to collaborate in developing viable products.

Nanotechnology Based Water Purifiers In The Indian Market

- **Puritech (Nanosilver coated Ceramic Candles) by ARCI, Hyderabad & SBP Aquatech Pvt. Ltd**

At ARCI, Hyderabad, the conventional method of ceramic candle filtration has been combined with nanotechnology to produce nanosilver coated Ceramic Candle Filters. In India, several people depend on these filters because they remove turbidity – but by adding nanosilver into the same material, water is also being disinfected from bacteria, providing a low cost and convenient solution. The price of the candle is ` 75 (£1) One disadvantage is that chemicals, if present in the water, remain.

- **TATA Swach by Tata Consultancy Services (TCS), Tata Chemicals and Titan Industries**

The TATA Swach is the result of years of collaboration between Tata Consultancy Services (TCS), Tata Chemicals and Titan Industries. The Swach which comes at 3 different prices – ` 499 (£7), 799 (£11), and 999 (£14) with a purification cost per litre of 10 paisa is a viable option for the BoP market. This filter uses silver nano particles infused in rice husk ash to purify water from bacterial contamination. It is non electrical and It has a simple fuse mechanism for end of use/ replacement indication that automatically shuts of water flow as soon as the purifying power of the filter bulb is exhausted. This filter won the gold award prize at the Wall Street Journal's Asian Innovation Award.

- **Aquaguard Total by Eureka Forbes Ltd. And IIT, Chennai**

Eureka Forbes has dominated Indian markets with their RO and UV based water purifiers. However, they have recently introduced a Nanotechnology solution to remove pesticides from water, developed by Indian Institute of Technology (IIT), Chennai, in their Aquaguard Total filters priced at ` 9590 (£130). While this technology can address all potential contaminants in BoP water supply, the price is a major barrier for access by the BoP.

- **Technologies Under Development**

There are also some relevant technologies at the development stage in premier research institutions in India and across the globe. Researchers at Banaras Hindu University (BHU), in a joint programme with Rensselaer Polytechnic Institute USA, have developed a method to produce carbon nano tube filters that efficiently remove micro-to nano-scale contaminants from water and heavy hydrocarbons from petroleum. More recently, carbon nano tube based water filters have also been developed and tested on the laboratory scale by Bhabha Atomic Research Centre (BARC), Mumbai[6]. A study by Indian Institute of Technology (IIT), Kharagpur has synthesized iron oxide particles using chemical method for arsenic removal[7]. Rice University, USA has also developed a prototype using nanorust, where nano iron binds with arsenic and is removed from water using a magnetic field. This prototype is being tested in Mexico.

In terms of **detection of contaminants** too extensive progress has been made. Researchers at Agharkar Research Institute have developed a simple device that uses gold nanoparticles for the detection of pathogens in 20 minutes. In IIT Bombay research on surface engineered nano particles for the detection and separation of toxic metal and organic dyes in being done and in IIT Delhi nanostructured sensors for water related safety and security are being developed.

- **Commitment to Funding**

Nanotechnology research in India has grown at a very fast rate, with an emphasis on water and energy sectors. The government has invested large sums in creating infrastructure and training scientists to further encourage this trend through their launch of a Nano mission in 2007. An allocation of Rs.1000 crore (£ 142 million) for five years has been made for the mission. The Department of Science and Technology (DST) is the nodal agency for implementing the Nano Mission. Although so far the focus has been more on nanoscience rather than its application to products DST is now coming up with workable models to give out grants for application and product development that is available on their website. Additionally, they are providing support for technologies from the lab to reach the prototype scale through the set up of a technology development board.

[6] Kar S. et al. (2008) 'Potential of carbon nanotubes in water purification: an approach towards the development of an integrated membrane system', International Journal of Nuclear Desalination, 3(2), 143–150.
[7] De D. et al. (2009) 'Iron oxide nanoparticle-assisted arsenic removal from aqueous system', Journal of Environmental Science and Health, Part A, 44 (2), 155 – 162.

The IBSA (India-Brazil-South Africa) nanotechnology initiative is a collaborative research and development programme between the Departments of Science and Technology in India, Brazil and South Africa for South-South collaboration on the promotion of nanotechnology for clean water. IBSA identifies three areas of research as high priority: Nanofiltration and ultrafiltration membranes; nano-based water purification systems for remote and rural areas; and carbon nano gels, nano tubes and nano fibres.[8] Industries are also on the look out for feasible nanotechnologies for products that meet their requirements of cost, performance, health and environment impacts and service and shelf life.

[8] http://www.ibsa-nano.igcar.gov.in/

Barriers in Providing Access to Safe Water

In the past few years, the Bottom of the Pyramid (BoP) has emerged as a dominant concept in business, driven by C.K Prahalad's "The Fortune at the Bottom of the Pyramid". The BoP population is the largest but also the most socio-economically disadvantaged group in the country. Given the enormous attention the concept has attracted, it has the potential to impact the world's billions of poor people especially through social marketing.

As seen above, the potential offered by this technology is vast. However there are technical, social and economic barriers that impede its uptake and usability. Our study threw up a multitude of challenges faced while providing the BoP, access to safe water using nanotechnology. These can be grouped as (Figure 4):

- **User challenges**
- **Technology Challenges**
- **Product Challenges**
- **Market Challenges**
- **Financial challenges**
- **Policy Challenges**

These challenges are detailed below.

- **User challenges**

- Awareness Levels

Awareness or the lack of **awareness** determines the practice and attitude of end users. People don't value products of water purification. The perception of people with respect to safe water is very diverse. Most believe that if the water appears clean, it is safe (Figure 3 sourced from our field survey). They are not aware of the risks of consuming contaminated water hence it is important to create awareness despite the technology adapted. The water and health-hygiene connect is very strong and can be used as a leverage point for awareness

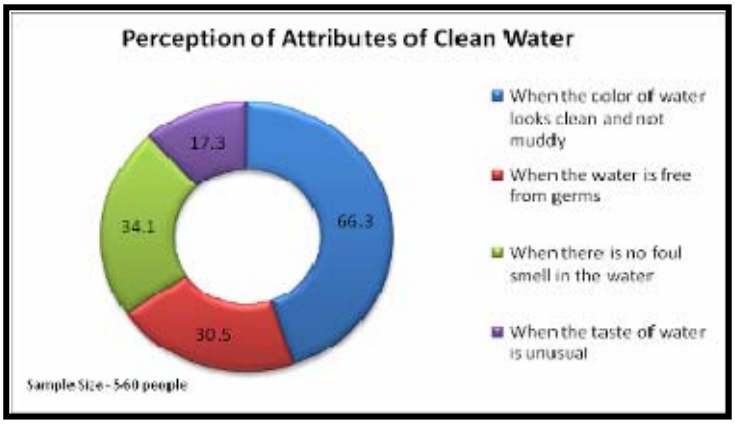

Figure 3 : Perceptions of the population on what constitutes clean water

generation. Growing health consciousness and an understanding of costs and expenditure related to diseases act as a push towards realizing the need for clean drinking water.

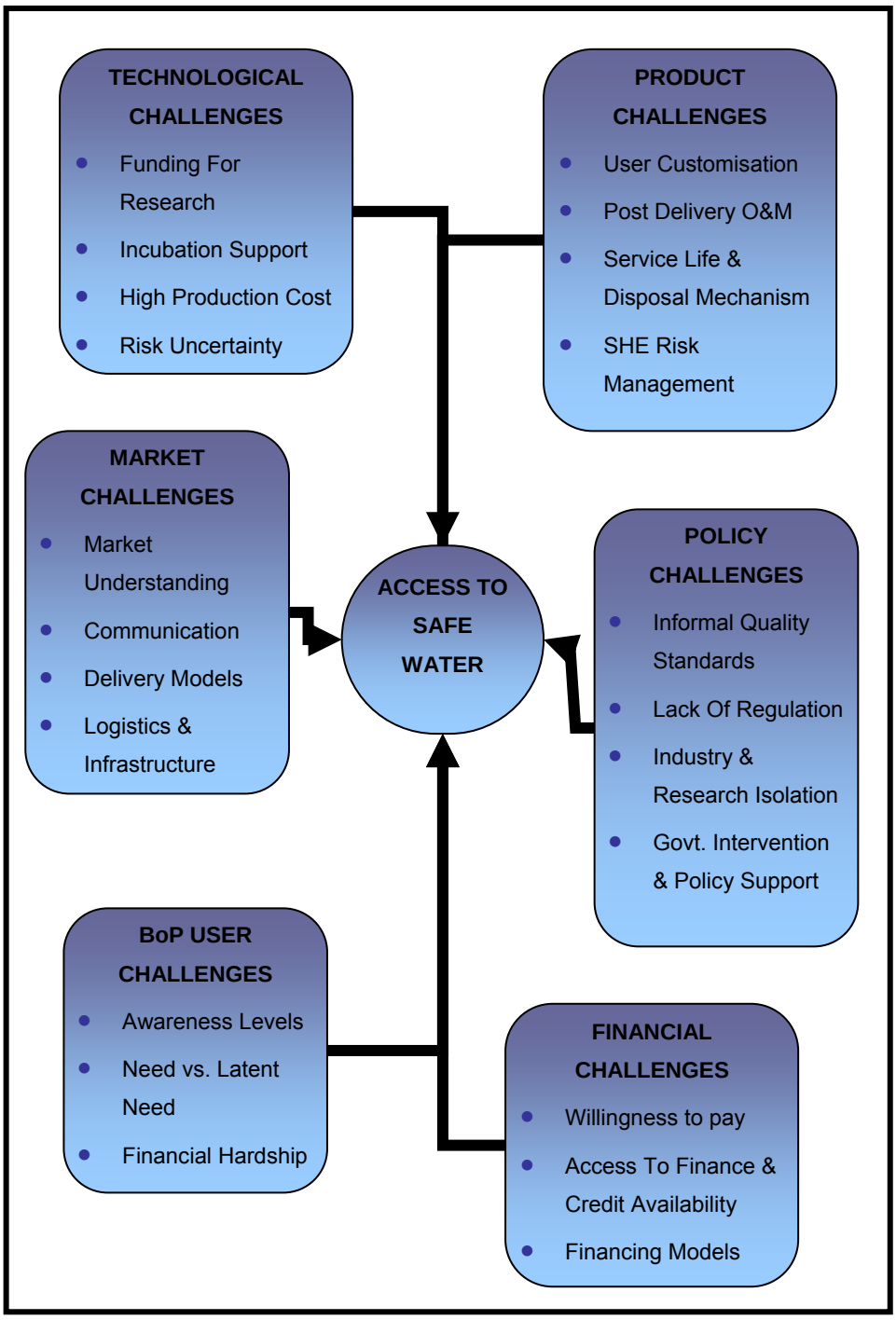

Figure 4 : Barriers facing Nanotechnology for BoP

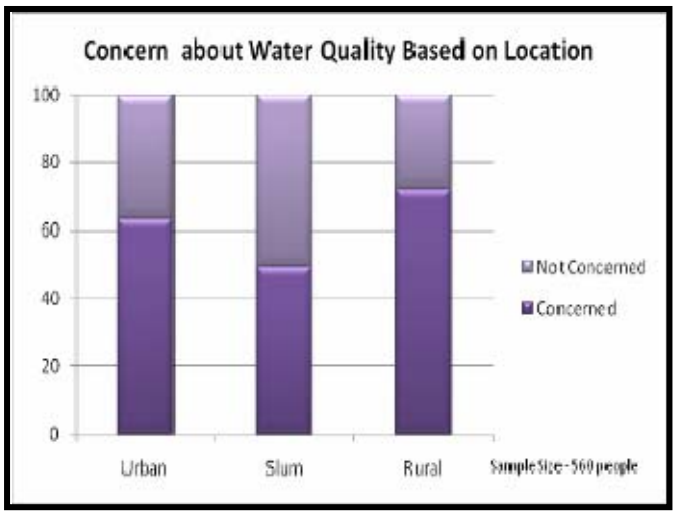

Figure 5 : Water Quality Concern among Urban, Rural and Slum Populations

- Need vs. Latent Need

Age old practices, market inefficiencies and government apathy have led BoP populations to deny or not recognise their latent needs and to pursue tangible needs. While water is important for survival, the concept of purifying drinking water is not very popular. People do not realize the importance of safe drinking water and the related health impacts. Our survey showed that while majority of the people are concerned about their water quality (64 per cent - Figure 6), the aspiration for owning a water purifier is not very high (31 per cent - Figure 7). Interestingly, rural BoP populations are more concerned (72 per cent) about their water quality than urban (63 per cent) and especially slum (49 per cent) populations (Figure 5). Boiling, filtering and decanting are the most popular choices for purification. The need for further treatment is not felt.

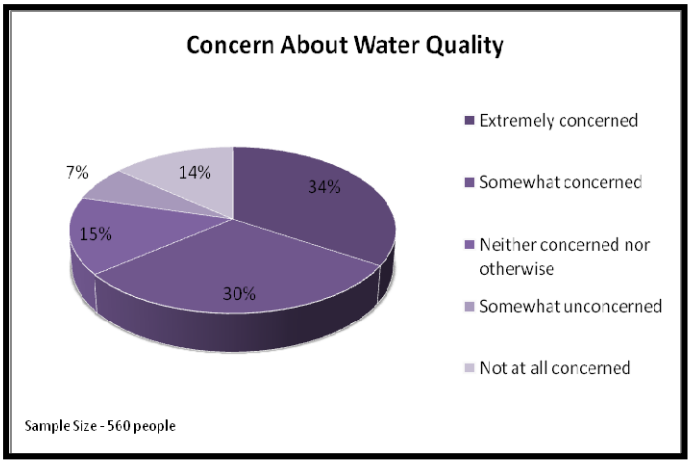

Figure 6 : Water Quality Concern Levels among the sample

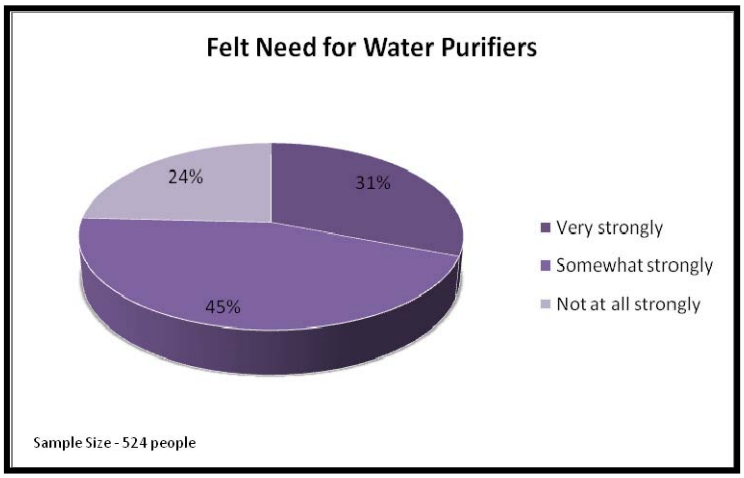

Figure 7 : Aspiration for Water Purifiers among the sample

- Financial Hardship

Income levels of the BoP are low in terms of per capita and disposable incomes. These households have nominal savings and liquidity, hence less adaptive capacity to absorb shocks. Also these products are expensive and hence out of reach for the BoP.

Figure 8 : Total BoP Spending by Income Segment

Source: WRI, The Next 4 Billion

As per a WRI report on the Indian Rural BoP expenditure, the water sector records only 0.1 per cent of the household expenditure. Over 70 per cent of the BoP expenditure in the water sector is from the urban markets (Figure 8)[9]. Water purification is not on the spending priority.

- **Technology Challenges**

- Funding For Research

Nanotechnology for water purification is a nascent science. There is a need for a lot of research and development before it can be mainstreamed in products. Most research is government sponsored.

There is a **lack of investment** in both **research** and **incubation** of technologies. There is a disconnect between academic researchers and corporate funding. Lack of ownership by government /NGOs, incubation support, investment in pilot incentive from government and synergy of supply chain are the other issues which impede a faster rollout (productisation) of the technology

- Incubation Support

Most research in the nanotechnology sector is in the laboratory phase i.e. testing the technology. Only a few have been prototyped and tested. The current **ability** of technologies to **scale up** is very **limited**. There is a **lack of emphasis** on the **incubation phase** that enables research and proven technologies to be marketable. There needs to be an involvement of key players – researchers, industry , end users

[9] Hammond A. et al, 2007, 'The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid', Worlds Resources Institute.

and policy makers – right from the design phase to ensure that a viable and user friendly innovation is brought out.

- High Production Cost

Currently the cost of production of nanomaterials is quite high. Though small amounts of material are needed, the level of purity required is very high. Also the size of the particle is critical to the efficiency of the process. Purification methodologies are expensive. This increases the cost of the technology and can make it unaffordable for the BoP target group.

- Risk uncertainty

Not many studies have been carried out to develop an understanding on the existence of any potential **risk** to the **environment or human health**. There is a **lack of knowledge** regarding **toxicity concerns** during manufacture and operation of the technology. Lack of scientific document for **safety** is a major gap behind the research and development of these products.

- **Product Challenges**

- User Customisation

Water storage and usage habits are peculiar to households and often dictated by region and culture. Devices need to be designed keeping in mind user preferences and cultural and traditional practices to enhance adoptability.

End users look for **instant gratification**. Water is a sector where providing instant gratification is often tough since health benefits are seen over medium and long terms. However there should be some visible result that the user can appreciate and that leads to an attitude change towards purifiers.

- Post Delivery O&M

Water purifiers require regular maintenance and service. The **lack of adequate, appropriate and timely technical support** alienates rural communities from easily adopting the purifiers. Lack of infrastructure, inaccessibility and lack of density act as deterrents for companies to set up an O&M supply chain. Survey inputs from retailers also highlight the lack of these services.

- Service Life & Disposal Mechanism

Filters have a pre determined life. If they are used beyond this period they will not be effective in removing the contaminants. In fact it may lead to further bacterial

contamination especially in the case of candles due to proliferation of the micro-organisms. End of life treatment and disposal mechanisms are often not clear or well established.

- Safety, Health and Environment Risk Management

Stakeholder consultations revealed that the probability and severity of risk are more during the manufacturing and disposal stage. Operation risk was perceived to be minimal. Probability and severity of risks is largely dependent on the scale of the unit, the process adopted for manufacture and the safety and management procedures followed. Smaller informal units appear to be more prone to risks.

- **Market Challenges**

- Market Understanding

Water purifiers are not very popular consumer goods especially in our focused target group. Results from our field survey show that only about 6 per cent of the target group use filters. They avoid new products that do not have much social proof[10]. There is a need to demystify (nano) technology.

Water purifiers cannot be marketed in the traditional sachet form prescribed for the BoP. Awareness and **understanding of the market** is **not adequate** especially in the BoP sector in terms of products available in market and how much do people spend for those products. There is also a need to understand the target audience and market and adequately assess their needs, so interventions can be moulded on their needs.

- Communication

A large majority of the target group are illiterate or functionally literate. **Lack of adequate and appropriate communication tools** is one of the major reasons for low awareness. New and affordable media and tools need to be used to reach the BoP populations and convey the message to them. Communication should be focused on changing behaviour to adopt purification techniques especially low cost and simplified methods like boiling, solar disinfection etc. thinking on low cost and effective marketing and media vehicles to reach BoP is required.

[10] Informational social influence where in individuals believe that others possess more knowledge or are better informed and accept their decisions and choices.

- Delivery Models

Water purification products can be classified as push-products that require intense efforts to promote and scale demand. The delivery model used to push these products is very important especially since the target market is a complex one.

It is also important to understand the meaning of cost at scale to understand delivery systems e.g. Bottled drinking water is very popular not only in the urban sector but also the rural due to its affordability. Cross subsidization is another approach to reach the last mile.

Another contention with respect to delivery models is the point of purification should be at the source or entry (community based models) or at use (household or individual level systems). Traditionally water is seen as public infrastructure to be provided by the government. Today however the government is failing to reach a large population, supplying only niche areas often at the expense of the BoP. The market is increasingly moving towards household level filters to ensure safe water reaches the last mile user. Our survey also reflected that the resistance towards purchasing an individual system (16 per cent) was much lower than that towards a community based system (36 per cent - Figure 9).

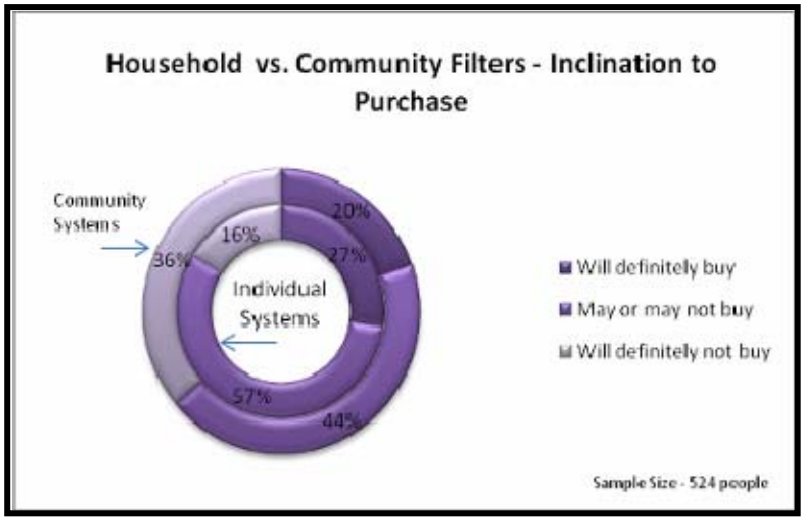

Figure 9 : Comparison between Individual and community water treatment systems

- Logistics & Infrastructure

Logistics of supply are a challenge due to the lack of adequate civic infrastructure. BoP populations are concentrated in rural areas, where infrastructure is not well established. The urban BoP population is situated in slums, often unauthorised hence services like roads, electricity and water are scare, erratic and unreliable. This added financial burden hinders appropriate and adequate reach for scale up and subsequent servicing.

- **Financial challenges**

- Willingness to Pay

Water is perceived as a free good. It is something nature provides, hence the willingness to pay for water is very limited. However as water purifiers are becoming popular with middle and high class urban populations, an aspiration is seen within the BoP. The BoP is also impacted by **BOP penalty,** where in they end up paying higher prices – monetary or in kind - for basic goods and services than do wealthier consumers. In the water sector, the upper classes benefit from schemes and subsidies applied on piped water where as the BoP receive water from contaminated sources or at a premium price. The most prominent reason to not buy a purifier, that came up during the survey was the cost (Figure 10).

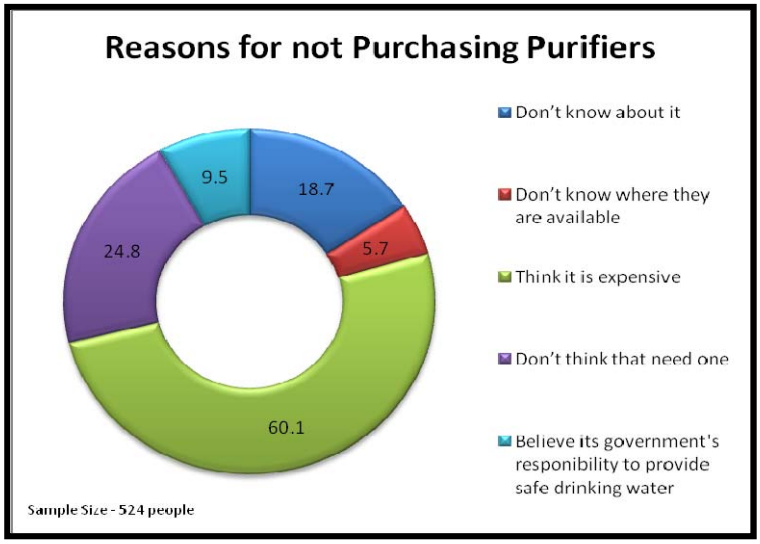

Figure 10 : Reasons for not purchasing purifiers

- Access To Finance & Credit Availability

Majority of this population does not have a bank account or access to formal financial services. Lack of permanent and formal housing is also an impediment in accessing these services. They often turn to local moneylenders who charge excessively high interest rates, also contributing to the BoP penalty Microfinance offers huge potential in this sector.

- Financing Models

There are limited finance models available for water purifiers. The two most prevalent ones are initial upfront payment and after paying EMI[11] over a set duration. Both cater to household level systems. Community models while advocated by many stakeholders have not taken off, especially since nanotechnology is not seen to be technologically ready to provide community based large scale treatment options.

[11] Equal Monthly Installments

- **Policy Challenges**

- Informal Quality Standards

The water purifier market is dominated by industry giants like Eureka Forbes, Kent, Phillips, TATA Chemicals, Hindustan Unilever etc. However the informal market especially for candle filters is a thriving business. Currently there are no norms on disclosure of information for this sector. Often it is seen that information on shelf life, service life, precautions, safety issues, replacement of filters, end of life indication, disposal etc. is not explicitly mentioned. The quality of the output water is also not assessed continuously to estimate the efficiency of the filter. The lack of standards on these parameters can lead to spurious products flooding the market.

- Lack Of Regulation

Despite, nanotechnology having penetrated the market in various sectors including water, there remains ambiguity on standards and regulations related to quality and risk management. **There is no legislation focused on nanomaterials, with respect to production, use and disposal.** The risks related to nanotechnology have not been adequately documented. While leaching risks during operation are taken care of, disposal risks during manufacture of the nanomaterial at laboratory and factory level as well as disposal of the device are not well documented. While efforts are underway by the government, the industry is moving very swiftly, increasing the probability of risk exposure to the population. There is a need to adopt the precautionary principle while dealing with this uncertainty.

- Industry & Research Isolation

During stakeholder consultations with researchers and industry players, the disconnect between the two key stakeholders was clearly recognised as a major barrier to research benefits reaching the masses. The lack of a common platform to share research findings and funding opportunities between and among the two groups inhibits interaction and further intensifies the isolation.

- Govt. Intervention & Policy Support

The **lethargy** displayed by **Government** agencies towards the above mentioned issues is seen as an overarching reason for concern. The lack of **risk support** to the research **enterprises** and the policy to establish and promote **entrepreneurship** and scale up **facilities** in institutes inhibits incubation and roll out of proven technologies to the field.

Emerging Approaches

Innovative Approaches To Reach The BoP

The Government is providing a whole lot of subsidies for rural initiatives and promoting programs like Financial Inclusion, Unique Identification (UIDAI), Internet and mobile connectivity for the BoP. While the BoP has always been on the Government and Civil Society agenda, there is growing industry interest in the $ 5 trillion global consumer market constituted by the four billion strong BoP population[12]. **Different products** and **approaches** are being piloted in various sectors like energy, health, finance, water etc. with varying degrees of success e.g. Shampoo sachets priced at ` 1-2, Project Shakti from Hindustan Unilever, Nokia Life Tools from Nokia, India which has empowered rural India with basic information, Narayana Hrudayalaya, an ultra low cost Hospital near Mysore which will be a super-specialty hospital to provide medical treatments at a very low cost, Vortex low cost, temperature resistant and energy efficient ATMs catering to rural markets.

One of the most successful sectors that have reached the BoP is mobile communication. India has a total of 811.6 million mobile connections, with about 35 per cent in rural areas[13]. Including the fixed line connections, the tele-density is over 60 per cent. This is quite significant given barriers of infrastructure and cost constraints. This has been driven primarily by the corporates. Innovations in developing low cost mobile phones are a key reason enabling penetration into these markets.

Another landmark innovation was in the area of refrigeration, from Godrej & Boyce called ChotuKool - provides all the functionality of a normal refrigerator but can run on a battery. Priced at ` 3250 (£ 46), weighing just 3-4Kgs it attracts not just the BoP but also top of the pyramid consumers who could utilize it for camping and other leisure activities. Product innovation tuned to the needs of the BoP is essential for a successful roll out of the technology and product.

In the water sector, **innovations** like the **nanosilver coated candle** developed by ARCI for less than £ 2 offer huge scope. Besides the **affordable costs** for the Bop, these candles can **easily replace** the older generation of ceramic candles in the existing filters, thus reducing resistance to new technology. A slightly more evolved

[12] Hammond A. et al, 2007, 'The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid', Worlds Resources Institute.

[13] Telecom Regulatory Authority of India (TRAI)

type of purifier, the **TATA Swach** range of **non electric** purifiers are perceived to be game changers - satisfying the essential necessity of purified water for the BoP for **costs** as **low** as £ 7 -10.

The energy sector has tried out a variety of approaches involving industry, NGOs, **existing retail** and **distribution channels** as well as creating **new Village Level Entrepreneurs (VLE)**. First Energy Oorja, a partnership between Indian Institute of Science, Bangalore and British Petroleum promoted their cook stoves through existing NGOs and their retail outlets. They also encouraged the mentoring of VLEs who transport and sell the stoves in neighboring villages. Companies like Prakti and Envirofit have also partnered with regional banks and micro-finance institutions to offer preferential financial lending services to the customers[14].

- **Innovative Approaches In The Water Sector**

The **microfinance approach** is being piloted in the water purification sector by Hindustan Unilever's (HUL) new product, Pureit - a water filter appropriate for the low income market segment. Priced at ` 2000 (£ 28), it treats pathogens and does not require a running tap connection or electricity to operate. After filtering 1,500 litres, the GermKill battery kit inside Pureit must be replaced at a cost of ` 350 (£5). HUL partnered with microfinance Institutions like BASIX, Access Development Services (Access), Spandana and Village Financial Services Pvt. Ltd. (VFS) to leverage microfinance institutions (MFIs) and local NGOs to facilitate and promote Pureit in rural areas. They present the proposition to their NGO and MFI partners and link them to HUL. MFIs often provide their clients with micro-credit to finance the purchase of Pureit water filters. The targeted 250,000 beneficiaries will be offered weekly repayable loans at zero rate of interest over a period of eight months[15]. HUL also promotes awareness campaigns to educate villagers about traditional methods of purification (e.g. boiling water) as well as the harmful effects of drinking contaminated water.

HUL's Project Shakti was started in 2001 to empower underprivileged rural women by providing income-generating opportunities - by selling soap, shampoo and other personal care products. The project has emerged as a successful low-cost business model and enhanced HUL's direct rural reach – armed with micro-credit; **rural women become direct-to-home distributors** of Unilever brands in rural markets.

[14] Shukla S. et el., 2011. 'The Base of Pyramid distribution challenge: Evaluating alternate distribution models of energy products for rural Base of Pyramid in India' Institute for Financial and Marketing Research
[15] Hindu Business Line print edition dated July 21, 2010

By selling directly to consumers, the women take on a role of influencers, strengthening their position in the local community. Margins are usually higher with the direct to consumer option than in the retail outlet option, where maximum margins are limited to 3per cent. A **rural sales promoter** is responsible for several villages at a time and provides a helping hand to the women as they grow their businesses. Following pilots in the south of India, the company is now using its **Shakti network** to distribute Pureit across the country.

Eureka Forbes has partnered with World Vision India with an aim towards developing comprehensive water purification products and solutions portfolios for the rural poor. They are working on a new business model for the rural markets, employing partners such as **Self-help groups** (SHGs) and **NGOs** who can provide water at the village community level on a profit. SHGs will purchase the customised water purification equipment, facilitated by World Vision through **micro-loans**, a unique feature of this **'public-private partnership model'**. The loans would be paid back over a period of time via payments from consumers of the clean water in the community. Eureka Forbes has already installed 150 plants in village communities selling water at 12 paisa per litre. It has also tied up with US based NGOs such as World Vision and Path for the same.

This partnership is also driving new innovations that would assist and empower relief workers in disaster situations to provide clean water. Early prototypes have already been deployed and the technology is now being assessed by World Vision International, Both organisations are working closely together to influence government policies pertaining to rural water provision and purification.

In India, the KanChan project distributes a slow sand filter device through local entrepreneurs trained by the Massachusetts Institute of Technology and the Environment and Public Health Organization. The entrepreneurs **gather materials locally, assemble** the slow-sand **device,** and **sell** the **finished product** at a 10 per cent profit margin[16].

The traditional top down approach used to address unmet needs for safe drinking water, among other basic necessities through direct public investments, subsidies, or other handouts have not been very successful. Other approaches including market based approaches need to be explored not just for the BoP but across the income segments. There is a need to innovate with respect to products, services and delivery

[16] Path , 2008, 'Activities and Stakeholders in the Global Water Sector: A Preliminary Analysis' , Path

models to ensure benefits reach the BoP and their needs – both felt and latent – are met at affordable prices. This requires substantial investment in capacity building and networking.

Paraphrasing Prahalad, we need to stop thinking of the poor as victims or recipients of hand me downs and recognize their value as consumers and contributors to the economy. They can inspire **innovation** in **technology** and **markets** leading to a new engine of growth.

Design Elements of Successful Approaches

Based on the understanding gained from stakeholder consultations and studying various approaches used to reach the BoP, there are some recurring themes that form the basis of a successful intervention. The BoP is a complex heterogeneous population with varied needs, united by the non-fulfilment of these needs. There is a need for innovation in technologies, products, services, and delivery models that are appropriate to BOP needs. This requires completely redefining and redesigning the way we approach the water issue.

The potential of a nanotechnology to meet safe water requirements in the BoP can be enhanced if it meets certain criteria that can serve as indicators to the potential feasibility of the technology. While the technology has proved its potential and ability to tackle a wide range of contaminants that cannot be achieved by conventional methods; its potential in the BoP has to be measured by its appropriateness in terms of the below indicators. These indicators are across the lifecycle of the product.

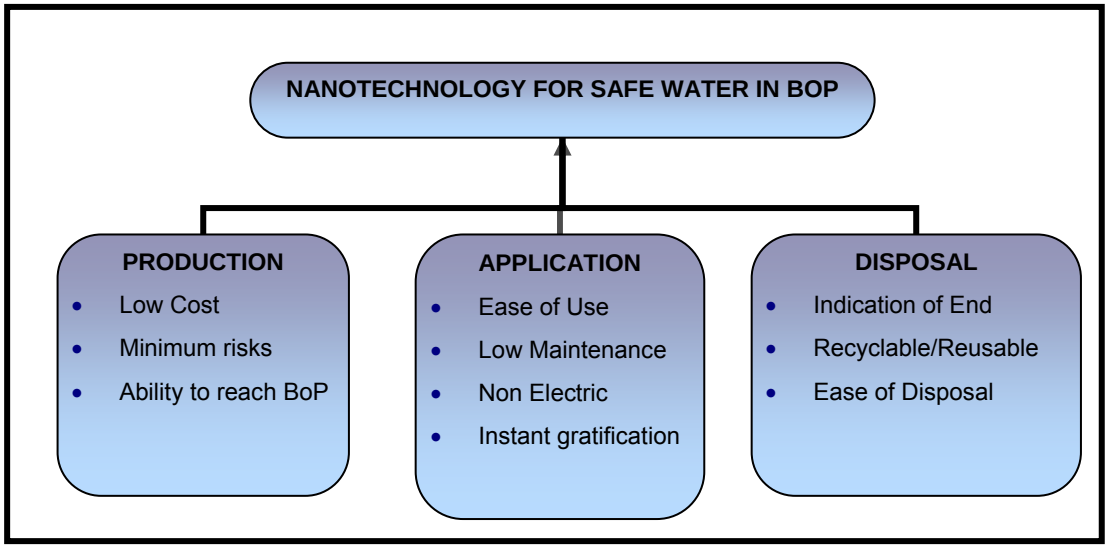

Figure 11 : Design Elements of Successful Approaches

A significant indirect indicator however is the awareness level that will determine the practice and attitude of the end user. Awareness – as discussed in the section on *Barriers* - has two important dimensions; the awareness towards the need for clean drinking water and the awareness about nanotechnology. The population needs to perceive the value of the intervention being introduced. Effective communication about the sources of contamination, health impacts of drinking contaminated water and the associated costs (medical, loss of productivity) of these impacts needs to reach the BoP.

In addition, the other indicators can be grouped under three heads (Figure 11):

- **Production**
- **Application**
- **Disposal**

These indicators are detailed below.

Production

- Given there is an appropriate technology and there is a demand for the same, there is still a concern of the services reaching the people. Cost is an important indicator as it dictates the movement of the device in the market. Though water is considered as a free resource, there is a price point that allows rural markets purchase or rent. This price point needs to be determined. The ability of a technology or device to be **mass produced at low costs** and **minimum risks** is a good indicator of its potential. High cost, low returns services will not be well accepted in the rural sector.
- The supply of material in required amounts at required purity is a concern for scaling up processes and has cost implications also. A **proper mechanism** for availability of **material** in markets would be a positive indicator of potential.
- Low risks indicate an ideal technology. This may not always be possible. **Good risk management practices** during production minimize risks and can be used as an indication of potential.
- Another set of indicators allude to the reach of the technology in the target market. The BoP has limited accessibility and affordability to water purifiers and complementary goods and services. There is a need to **enable access** through innovative delivery models – business or developmental – and **financing approaches** and through novel distribution strategies and channels. E.g. cross-subsidies, community-based systems, SHG distribution channels, micro loans etc.

- An **established distribution channel** with **extensive connectivity** in target populations would enhance potential. Our survey shows that retailers believe the introduction of support services like credit facilities, schemes and advertising would enhance sales (Figure 12).

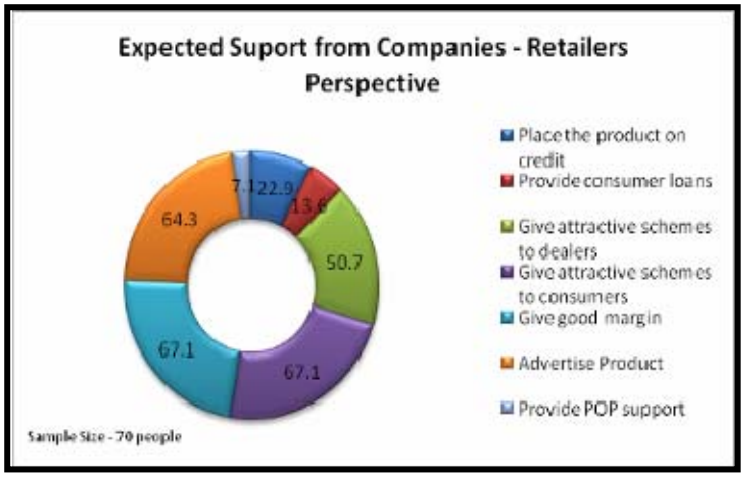

Figure 12: Support Services Retailers expect from Companies to increase Sales

- **Post sale or delivery service infrastructure** is often a cause of concern especially in rural markets and is indicative of the success in markets.

- **Application**

A very important set of indicators that came up during the discussions were those related to end user specifications and preference.

- End users look for **instant gratification i.e.** immediate benefits. This is a very important indicator in assessing the potential of a prospective technology. Water is a sector where providing instant gratification is often tough since health benefits are seen over medium and long terms. However there should be some visible result that the user can appreciate and that leads to an attitude change towards purifiers.

- Water storage and usage habits are peculiar to households and often dictated by **region** and **culture**. The purifier **design** should take into account this parameter and be easy to use to increase its potential success in the BoP. It needs to be attractive at the same time not too complicated.

- To enhance potential in BoP markets of India, it is important that the technology is energy efficient and preferably **non – electric** since several rural areas still receive erratic or no electricity supply. Other user friendly criteria such as **ease of use**, low **maintenance**, no change in spare parts and **durability** of the product are also significant indicators (Figure 13).

- The **name** of the product should be selected in such a way that it can be related to by the end users and also indicate the service provided. E.g. TATA Swach (Swach = Clean), *Pure*-it, Aqua*guard*.

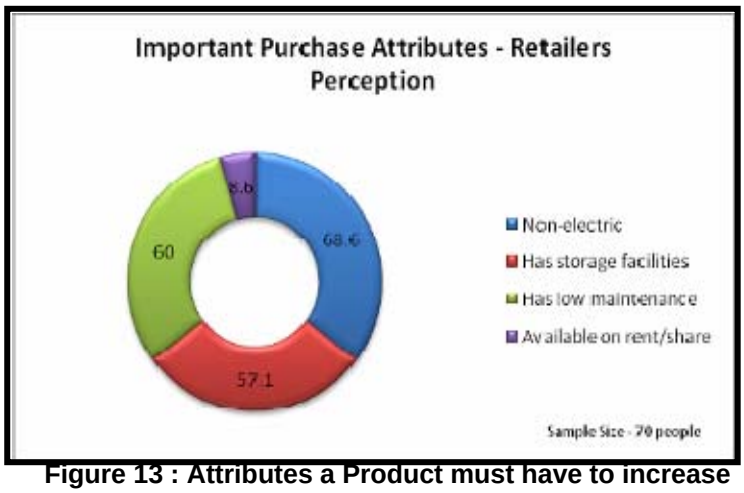

Figure 13 : Attributes a Product must have to increase acceptance as per retailers

- **End of Life**

Taking into account health and environment consideration the end of life indicators are also of immense importance.

- Primarily, users should receive a **simple indication** about the **end life** of the product to avoid overuse that may be harmful.
- The disposal also needs to be considered taking into account both the toxic chemical residues and the e-waste generated from the device. Disposal of toxic materials should be done through proper routes. **Appropriate disposal mechanisms** form an indicator of sustainability.
- Also less polluting materials across their life cycle are preferred – Thus the **recyclability or reusability** of filters is also an indicator.

In conclusion, the proposed approach is a multi-stakeholder one. It is important to get various stakeholders like policy makers, NGOs, researchers, technologists, industries, funding agencies together on a common platform - using Workshops, showcases, symposia, websites etc. - to be able to incubate and nurture the researched technology.

Way Forward

Based on the findings of Phase 1 of the study, the need for action research on certain key issues have emerged. Nanotechnology is *the* technology of the future. However, it comes with uncertainties about potential risks along the lifecycle, which are yet to be completely understood. Nanotechnology has the potential to penetrate BoP markets with the right delivery models, innovative partnerships and well defined policy-practice connect.

Given this scenario, in the next phase, we aim to focus on piloting action research on the following lines.

- **Pilot unique and innovative partnerships and service delivery models and test their potential for scale up**
  - Using innovative communication tools for awareness and to bring about behaviour change among the BoP in order to enhance acceptance of solution
  - Leading to development of a regulatory risk management framework for nanotechnology based products by creating a *practice to policy* connect.
- **Develop a global multi-stakeholder platform in order to facilitate**
  - Knowledge sharing and dialogue – on nanotechnology benefits, associated risks and their management and regulation
  - Partnerships between key stakeholders like researchers, industry and end users

Several stakeholder groups have expressed interest in collaborating on the action research in the next phase. We shall be proactively seeking partnerships with key groups from among the following:

Nanotechnology Market Leaders - Eureka Forbes Limited, TATA Chemicals, HUL
Nanotechnology R&D - DST, ARCI, Agharkar Research Institute, IIT- Bombay, Stanford University, Aberdeen University
Lifecycle / Risk Assessment and Management – Indian Institute of Toxicology Research, The Energy and Resources Institute
Financing Institutes – International Finance Corporation, Microfinance institutes
Policy Environment - Central Pollution Control Board, Ministry of Environment and Forests, Nano Technology Mission of DST, Rajiv Gandhi Drinking Water Mission, Ministry of Water Resources, Government of India

Annexure

- **Consultation Summary – April 2011**
- **Consultation Summary – March 2011**
- **Secondary Research Report**
- **Market Research Survey**