Access to Safe Water for the Bottom of Pyramid : Strategies for Disseminating Technology Research Benefits

Technology Packaging Study

Submitted by

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1. Introduction

Access to safe water is one of the major issues facing the world today. Nearly one billion people - one in eight persons in the world - lack access to safe water supply. Over 3.5 million people die each year from water-related disease; 84 % are children. 98 % occur in the developing world[1]. New and emerging technologies such as nanotechnology have the potential to revolutionize the way we address access to water. However the challenge lies in the enabling access to the technologies for these millions. In order to address the issue, the Development Alternatives Group (DA) is currently engaged in a DFID supported initiative on exploring the application of nanotechnology for water purification for the Bottom of the Pyramid (BoP) population.

During phase I of the initiative, a study was undertaken on the potential of Nanotechnology to provide safe drinking water to the BoP populations at low cost. The study brought out that there is research evidence for various Nano materials which can effectively remove bacteria, viruses, protozoa, pesticides, heavy metals, inorganic contaminants etc. This technology has the potential to make the cost effective filters to reach the masses as very small amounts of material is required, However, in spite of the potential the technology has, it has not captured the mind or market among consumers. 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. Nonetheless, the study also found that nanotechnology research benefits can reach the BoP, through innovative and appropriate delivery models.

The study highlighted that there are (Nano) technologies that can effectively purify water and there is a large population in need of these technologies. However, there is a disconnect between the two. Thus, the need of the hour is to make an attempt to bridge this gap and provide with safe access water. The DA Group seeks to address the problem of safe drinking water to the BoP population. DA is exploring and evaluating Nanotechnology as a potential solution that can deliver affordable and effective solutions for water purification, providing access to safe drinking water to millions of people.

DA has undertaken a technology packaging study to understand the supply chain and the life cycle of the products in different domains so that the findings can be incorporated in the final

1 The Water Project

pilot roll out and try to look into various aspects like product design, standards and practices for quality assurance, awareness, safety aspects from the point of view of each stakeholder.

The first chapter introduces the initiative and lays the context for the study. The second chapter maps short listed nano based technologies both at the research and market stages. The pilot will take forward some of these technologies. Chapter 3 traces the life cycle of a water filter right from the research stage upto disposal. It also highlights key issues that need to be considered while planning an intervention. Chapter 4 further expounds on innovations undertaken by various stakeholders to enable access to the BoP. The last chapter throws up pointers for the stakeholders to improve access.

2. Technology Mapping

This chapter focuses on mapping existing technologies in the market and the technologies which are in the developing stage.

2.1 Market Phase

There are a few nano based technologies that have penetrated the market. Majority of these are silver based technologies. The table below compares the five technologies that have the penetrated the market in terms of their technical, environmental and economic parameters. It was found that there was a complete lack of information available related to environmental and risk management aspects. Though the lost cost filters have been introduced in the market almost eight years back, there is alack of penetration in the BoP markets.

For more information refer to annexure 1

Figure 1: Various nano based products in the market. Puritech Nanocoated Candle (top left), Aquaguard Total (top right), TATA Swatch (bottom left), Purit classic (bottom centre), Lifestraw, Westerguard (bottom right)

Table 1 : Technologies in the Market

Parameters	Puritech	Aquaguard Total Infinity	TATA Swach Smart	Pureit	Lifestraw Family	Tulip Siphon Water filter
Product Innovator Details	International Advanced Research Centre for Powder Metallurgy and new Materials	IIT - Chennai	TATA Chemicals Pvt. Ltd.	Hindustan Unilever	Vesterguard Lifestraw[2]	Basic water Needs Netherlands
Manufacturer	SBP Aquatech Pvt Ltd,	Eureka Forbes	Titan Industries	Hindustan Unilever	Not disclosed	Basic Water Needs India Pvt. Ltd.
Marketed On	2009	2007	2009	2004	2005	2008
Storage Facility	Storage type (attachment with normal filters)	Storage type	Storage type	Storage type	Fill and draw	Non-storage
USP	Nano silver impregnated ceramic candle used for anti-bacterial action	Nano silver technology in the form of carbon blocks, 7 technologies to cure 17 different water conditions.	Nanotech water purifier with special TSRF Technology in TATA swach bulb	Meets stringent criteria of Environmental Protection Agency(EPA), USA for removal of harmful bacteria and viruses	80 microns mesh which prevents the particles larger than this size	Nano silver impregnated ceramic candle used for anti-bacterial action
Availability Of Literature About Product	As the product is discontinued so not much details are present	Purification process, product specifications along with the FAQ's are provided.	In the form of FAQ's the issues that a user can have are described properly and also the maintenance	Very insightful literature covering major issues that could come and various causes and actions to be taken	Literature includes the detailed working of how the water is being purified and the maintenance of the product.	Product literature and details are available on internet

[2] http://vestergaard-frandsen.com/lifestraw/lifestraw/longevity-and-efficacy

Technical						
Way Of Nanotechnology Application	When passing through the candle bacteria comes in contact with the Nano-silver particles and gets destroyed.	Water passes through the clarity cartridge which removes the physical impurities and then through the silver cartridge which removes organic impurities, excess chlorine, harmful lead, pesticides.	Processed rice husk ash impregnated with Nano silver reduces the turbidity and the carbon binds with and adsorbs pesticides and fertilisers	Water passes through Microfibre mesh which removes visible dirt, then through carbon trap which removes parasites and pesticides and finally through Germkill processor which releases chlorine and removes viruses and bacteria	Water flows with the help of gravity and it gets purified with the help of a porous membrane of pore size 20nm.	When passing through the candle bacteria comes in contact with the Nano-silver particles and contamination gets destroyed.
Contaminants Addressed	Bacterial contamination	Harmful bacteria, virus, pesticides, chemicals and other impurities	Bacterial contamination	oil, sand, soil, clay, dirt, decayed animal and plant waste, and harmful pesticides	Bacterial contamination	Bacterial contamination, turbidity
Filtration Rate	1 liter per hour	120 liters per hour (max)	3 to 4 litres per hour	1.8 litres per hour	12-15 liters per hour	4-5 liters per hour
Product Performance Certification	No certification as per the information till now	Indian medical association certified	Central Food Technological Research Institue, Mysore AES, UK KEM Hospital, Pune	London School Of Hygiene and Tropical Medicine, Indian Public Health Association	Complies with the regulations of EPA, USA	Product performance test certificate done EMS Lab Aurobrindavan, Auroville, T.N, India – 605101 and by Sargam laboratory, Chennai
Working Life (Volume)	1000 – 1200 liters	6000 litres (approx)	3000 liters or six month of use whichever is early	1000-2250 litres	18000 liters	3000 - 7000 liters
Energy Needs	Non-Electrical	With AC electricity	Non-Electrical	Non-Electrical	Non-Electrical	Non-Electrical

Environmental						
Disposal Indicator & Information	Not disclosed but proper system should be there is also felt by Dr. Rao	Usually the candle and carbon filter are replaced after 1 year	Indicator there to let the user know when the replacement is required.	Practice to dispose of is to throw in a dry waste[3] and also an indication light for the end of life.	Water stops flowing when the pores are blocked. Replace then.	No information given
Environment Impact &Risk Information	No information available	No information available	No information available	No information available	No information available	No information given
Economical						
Market Availability	Limited	Available in market widely	Available in market widely	Available in market widely	Kenya, police and military in India, now in USA and Canada	Available widely in market
Product Price	Rs.130/ candle	Rs.11490/-	Rs.799 – 999/-	Rs.1000-6900/-	Around Rs.1200/-	Rs215/-
Replaceable Part Cost	Rs.130/ candle	Rs.1125/-	Rs349/-	Rs.365/-	No replaceable part	Rs95/-
Product Delivery Mode	Retailer	door to door Retailer	Retailer door to door	Retailer	Website in USA and Canada	From manufacturer itself
Customer Care	No information disclosed	Present named Euro helpline (39883333)	Sales facility along with customer grievance cell (1800-2-585858)	Available across India (1860-180-1000)	Not much related to India as it is in early stage	No information given
Comments	The technology was implemented but the response and current status is not known	It is widely available since its launch. However, cost and requirement of electricity makes impact population less.	Widely available and cost is less compared to the other products with bacteria removal but not able to reach the BoP population	It is widely available. Not a low cost filter but able to reach BoP with its micro-finance model.		Initially in India product Was marketed through commercial channels but now it is being promoted through NGOs

[3] http://www.pureitwater.com/IN/faqs#ans1

2.2 Research Phase / Incubation Phase

Besides the technologies in the market, there is a range of Nano based research being carried out in laboratories across the world. While most of these technologies are still at research level, a few have been productized and are being incubated. Many of these technologies have a specific developing country focus. This section highlights a few of these technologies.

- **Stanford University**[4]:

Researchers from Stanford researchers have developed a water-purifying filter that makes the process more than 80,000 times faster than existing filters. The key is coating the filter fabric – ordinary cotton – with carbon nano-tubes and silver nano-wires, and then electrifying it. The research was led by Stanford materials science and engineering professors Yi Cui and Sarah Heilshorn. The idea was to make water purification available for everyone at low cost, especially in developing countries.

The product is such designed that it does not trap the bacteria, it lets them pass through the highly conductive Nano-coated cotton. It uses electrical pulses to inactivate bacteria by poking holes in their cell walls. The main advantages are the speed of filtration and the low power requirements. This technology is quiet impressive with the facts that cost has been kept low so that it can be provided to the BoP population. The product is in testing phase currently.

- **University of Aberdeen:**

Scientists at the University of Aberdeen have been developing a new technology that uses a sunlight-powered catalyst to treat contaminated water. Scotoil Services is leading the project, in partnership with the University of Aberdeen, Yorkshire Water and OpTI Technium. The photoelectroncatalyst is mounted into an electrochemical cell is used to decontaminate the water and by-product of this process is that it purifies water as well as creates electricity.

Under the laboratory conditions the scientists have been able to recover currents of the order of milli amperes and in the final prototype it is expected that under the application of multiple cells enough electricity could be generated to run a motor or a pump. However, the primary focus while developing the prototype will be on water purification.

4 http://news.stanford.edu/news/2010/august/nano-pure-water-083110.html

- **Stellenbosch University**[5]:

Prof. Eugene Cloete and his colleagues at the Water Institute of the University of Stellenbosch have come up with an inexpensive, teabag-like sac of Nano-fibers which purifies the water when water passes through it. The filter cannot desalinate the water nor can it clean acid mine drainage. It is most suitable for cleaning running river water in rural areas where there is no contamination from heavy industrial development and direct disposal of untreated sewerage.

The team is trying to upscale the product by getting the laboratory tests done to ensure that it meets the necessary criteria. The effort of the team is appreciable as they have succeeded in making a low cost solution for providing the safe water but the limitation of this is that the impact population will be limited because of the constraint that it requires running water to purify and also that it should not be contaminated by the industrial or untreated sewerage waste.

Thus, by looking at the technology mapping of the various products which are in market or at developing stage, a technology will be finalized keeping in mind the technology that provides safe drinking water without any side effects e.g. depletion of nutrients, any bacterial or any other type of contamination; low cost to make it affordable for them; impact of the product on the environment and on the people handling the material either in manufacturing, assembling, transporting or final user; disposal management, a system in place to manage the disposal of the product in order to prevent its side-effects.

- **IIT Bombay**

In Indian Institute of Technology, Bombay there is a lot of research going on in the field of Nanotechnology that can be further used in water purification. In IIT-Bombay research on surface engineered nano particles for the detection and separation of toxic metal and organic dyes in being done. Dr. Dhiren Bahadur with some colleagues is working on removing toxic metal ions (Cr3+, Ni2+, Co2+, Cu2+, Cd2+, Ag+, Hg2+, Pb2+ and As3+) and microorganisms (Escherichia coli(E. coli), Sarcinalutea (S. lutea) and Staphylococcus aureus (S. aureus)) from waste water. Recently, magnetic Nanoparticles (MNP) such as Fe3O4 and gamma-Fe2O3 have been investigated to resolve various environmental problems, such as removing toxic metal ions and radioactive elements, capturing of microbial pathogens and organic dyes, accelerating the coagulation of sewage, and remediation of contaminated soils. The magnetic

5 http://www0.sun.ac.za/water/main_eng.php?cata=nanotechnology_and_filtration&id=5

nanoparticles possess high surface area and optimal magnetic properties, which lead to high adsorption efficiency, high removal rate of contaminants, and easy and rapid separation of adsorbent from solution via magnetic field and are reusable. In order to achieve this, new and effective aqueous stabilized surface engineered/surface functionalized magnetic nanoparticles with low regeneration cost are needed on which the research is in action. However, the research in this area is in its nascent stage and detail investigations are required to establish the large scale purification of water in real life.

- **IIT Chennai**

One of the research groups of IIT- Chennai are looking at the possible use of noble nanoparticles for water purification. The interactions of the noble Nanoparticles with organochlorine and organophosphorous pesticides are being studied. Specifically the nanoparticles for study are Gold and Silver whereas the pesticides used are endosulphan, malathion and chlorpyrifos.They followed this study from the findings regarding the possibility of degrading different halocarbons using noble metal nanoparticles.

For more information refer to annexure 2

3. Life cycle

The product life-cycle is the total time span since the birth of the product till the time it is disposed of. The major stages of the life cycle of a product are:

- Research stage,
- Production stage,
- Supply stage,
- Usage and Disposal stage.

The study on life cycle is done to understand the movement of the water filters through the various stages. These studies will provide insights into the kind of inputs that need to be fed into various processes in the supply chain. The findings and learnings from this study will be incorporated with the business model in the pilot phase.

The schematic below represents the main stages in the life cycle of a filter. Each stage is then detailed out separately with respect to the key functions and stakeholders.

3.1 Research stage

The research stage is the first step in the life cycle of a product. In this stage, we critically look at various aspects of technology development and technology transfer including risk management, precautions taken while handling nano materials. Research is primarily conducted in laboratories. These laboratories could either be academic research units or industry R&D centers.

Academic Laboratories: These centers are mostly affiliated to universities and are government funded agencies. Researchers work in teams on various issues. Very often research remains academic in these situations, as there is no formal mechanism to ensure that the research sees the light of day. Some laboratories are affiliated with incubation centers that take forward the research and create products that can reach the target group. There have also been instances where research laboratories have tied up with industry houses or entrepreneurs and the technology developed has been productized and marketed.

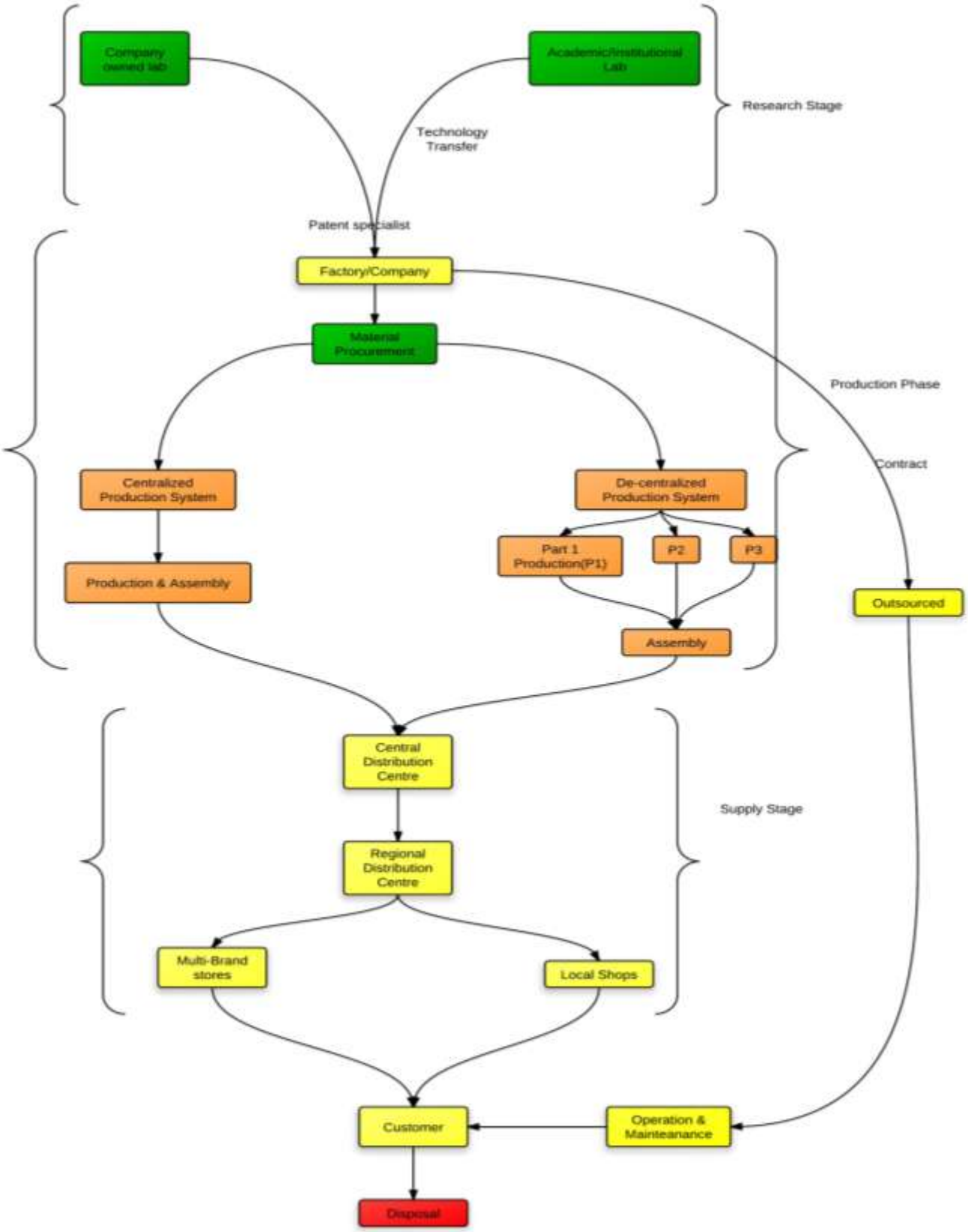

Figure 2 : Schematic representing the Life cycle of a water purifier

The technology in the Aquaguard Total Infinity, was developed and patented by Dr T. Pradeep and his team at Indian Institute of Technology, Chennai (IIT-C). When Eureka Forbes (EFL) learnt about a potential technology to remove pesticides from water, they approached IIT-C to collaborate and get a joint patent on the device, which is now being marketed under their banner. Similarly in Hyderabad, ARCI and IMMT jointly developed the nano silver based candle. This was being produced and marketed by SBP Aquatech PVT. Ltd. The technology was handed over to them and field tested in villages of Andhra Pradesh.

Industry R&D centers: Many companies invest a certain part of their profits back in R&D to explore and develop new products and services to enhance their business portfolio. These centers often fulfill both research and incubation functions. The TATA Swatch was thus developed harnessing the expertise of in-house scientists within the TATA group.

Handling patent and Intellectual property rights (IPR) related documentation is generally outsourced and handled by specialized consultants.

Disclosure of information on the nano material used and handling and disposal guidelines is inadequate. Not enough research has been carried out on the long terms effects of these material on human health and the environment.

Another important aspect at this stage, is the design of the product. Designing is primarily an incubation function. The design needs to include ergonomic and user behavior patterns. This has to be done while keeping costs low so as to enable access to the BoP.

3.2 Production Stage

Once a technology has been developed and tested, the next step towards getting it into the market is to develop a product. The product design is either done at the laboratories itself or in conjunction with the industry. The industry then is responsible for mass scale production of the product. The two key steps in this process are:

- Procurement of raw material
- Production and Assembly of the unit

Procurement can be undertaken through various methods. The below mentioned methods are applicable for the competitive markets.

- Invitation of Bids: The bids are being called through print media. Various companies send their bids in sealed envelopes and depending upon the needs of the product the winner of the bid is decided. Standards and the firm specifications are clearly specified. But the problem in this system is that the environmental issues are not taken into consideration while inviting the tender.
- Request for proposal: It is used where the needs cannot be quantitatively or qualitatively expressed in sufficient details to allow use of bidding method. So, the proposals are called for and on the basis of the understanding of the proposal the procurement agency is decided.
- Direct contracting: It is the scenario where there is monopoly in the market. When no competitor is present there is no alternative but to give the order to the only organization present.

Once the material has been procured, the next step is production and assembly. This can be a centralized or decentralized process.

- **Centralized production and assembly**

Here the production and assembly is carried out at one location. They are then transported to various distribution centers from this centralized production unit.

In the case of Usha Brita, the production and assembly is done at Bhaddi, Himachal Pradesh and then the product is transported to Naraina and Nangloi in Delhi for distribution to different places in India.

Hero Moto Corporation, have 3 production sites at Dharuhera, Haridwar and Gurgoan. They produce the products there and distribute from there itself.
In the case of Tata Nano, it is being imported to Malaysia in parts. It will be assembled in its two factories there. All Tata Nano cars will be distributed through the four distribution centers only. Orders can be made vide these distribution centers or its web site.
At Maruti, outsourcing of various parts are done like in Manesar, Haryana where the engine is made at Suzuki Power Train Limited and the crankshaft at AMTEK Auto Pvt. Ltd. and at its own plant in Manesar and the assembly is done at the Maruti's plant in Manesar.

- **De-centralized production and assembly**

Here production and assembly happen at different or multiple locations. Various permutations and combinations are possible. E.g. production of different parts is done at different places and assembly is done at one place or production happens centrally and assembly is done at various locations to cater to different markets.

The carbon blocks used in the Eureka Forbes Limited (EFL) product Total Infiniti are made in Bangalore while the assembly is done at the Dehradun plant from where the product is transported to their regional distribution centers.

In some cases the production and assembly is done at multiple locations and are distributed from there. Pepsico India has 38 bottling plants in India and the packaging and distribution is done from these plants themselves.

Table 2 : Different production systems

Property	Centralized Production	De-centralized Production
Cost	Less in comparison to De-centralized	More because of increased costs in managing as human resources needed are more
Efficiency	More in this case because it is easy monitor a single unit	Less than centralized as it is difficult to manage multiple units
Customization	Not possible	Can be customized according to the demand region-wise

Analogies can be taken from these kinds of production systems while designing and rolling out the pilot.

3.3 Supply stage:

This stage includes the distribution and transportation of the product from the production facility to the consumer. This stage includes various stakeholders ranging from suppliers, manufacturers, warehouses, distributors, retailers, salesmen, etc. This is an important step from the point of view of costs involved as well as customer demand and satisfaction, and finding the right balance is critical.

Multi dimensional tools and strategies are followed to reach the customer. Like door to door salesmen, company websites, different online shop websites and retailers. Some of the key strategies are described below.

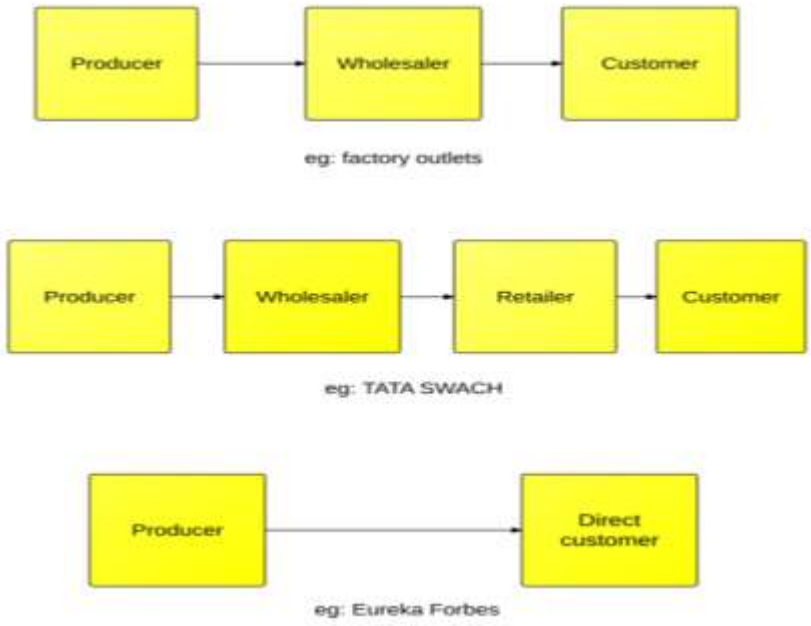

Figure 3: Different distribution systems followed

- **Producer-wholesaler-customer**

This is one of the strategies companies follow to reach the customers. There is only one link between the consumer and producer. This enables them to supply at lower costs. e.g. factory outlets of Nike, Adidas etc. Factory outlets are typically manufacturer branded stores and are used to expand their reach and make products more accessible to customers. Here the products are available at discount always. This becomes possible because the number of players through which the product is being exchanged is reduced.

- **Producer-wholesaler-retailer-customer**

This is the most common and easily reachable process that is being followed to reach the customers. The product is transferred to the distributors at a central, regional and then local level. Fro there on it moves to the retailer from where the end user can purchase it. The retailers can be exclusive to the brand or one that stores similar kind of products from a few select brands. There are also retailers who stock all kinds of products like the local grocery or everyday need shops. Majority of the enterprises follow this method e.g. the HUL Pureit, TATA Swach, are the examples where this chain is being followed.

- **Producer-direct customer**

This is one of the cases where the company keeps the sales channel completely to itself. There are no distributors or retailers involved. Door-to-door sale is a classic example of this

strategy. Amway followed this model with a huge network of direct sales people. Another recently introduced one is the online shopping system. Through this the companies have penetrated deeper increasing the reach while minimizing on costs as there is no need to maintain a physical shop.

In some cases a hybrid model has been adopted. Eureka Forbes Limited has adopted the door-to-door sales strategy. They have also stocked their product with retailers. Whenever they receive a request either through the website or a customer care call they pick up a product fro the retailers and show the customer a demo and sell the item.

- **Innovative Approaches**

Besides these mainstream approaches, some companies have adopted innovative mechanisms to reach their markets especially the BoP market. Many companies like EFL and HUL have included NGOs and Micro finance institutions in ensuring their reach. They also involve women self help groups (SHGs) in the supply chain providing them employment and trying to raise their standard of living.

The HUL Shakti Project is HUL's rural initiative. It seeks to empower the underprivileged rural women by providing income-generating opportunities, health and hygiene education through the Shakti Vani Programme, and creating access to relevant information through the iShakti community portal. Started in 2001, Shakti has already been extended upto 80,000 villages in 15 states and has about 25,000 women entrepreneurs earning Rs.700 – 1000 per month which is twice their average household income. They are also distributing their low cost water filter through this network. HUL has a product that costs around USD 30 collaborated with Spandana, a local Indian Micro Finance Institution. In two centers in Tamilnadu customers pay little less than a US$ 1 per week for 50 weeks and in two other centers, they pay US$ 2 per week for 25 weeks.

Similarly EFL has tied up with NGO WorldVision and Basix Microfinance to supply rural women SHGS with parts of their filter on an easy loan. The gourps then assembly and sell the units for a small profit.

- **Marketing**

Marketing is another key step engaging with customers and creating awareness about a product. A preliminary market survey conducted in New Delhi threw up that customers have almost no knowledge about the technology used and its pros and cons.

The two things that do influence customer choice are the brand name and the cost of the product. The advertising campaign plays a critical role in establishing the brand name and creating recall value for it.

The biggest driving force behind the demand of a product is its marketing strategies. TATA launched its low cost water purifier TATA Swach in 2009. the uptake in the market was not very high. In order to generate awareness on water quality issues and promote their product, they launched Awareness Drive on Safe Drinking Water in June 2012.

In addition to that they have their presence in the retail market. Also, they are promoting their product online increasing their customer reach. So, a multi-dimensional approach is being followed by TATA to reach the customer.

3.4 Use and disposal

This is the last step in the life of a product. It is also one of the most difficult to track due to the sheer volume of stakeholders who are involved in the chain. Once the product has been bought, it needs to be maintained properly to ensure that it is effectively purifying water.

- **Operation & Maintenance**

In many cases, the operation and maintenance of the product is taken care by the company itself. They have their customer care cells to attend to customer needs and complaints. They have set their response times. Few companies like Whirlpool give customers a “satisfaction code” which the customer gives to the maintenance person if they are satisfied with the service. Many companies also outsource the maintenance part and have bi-yearly or yearly reviews. The customer after a predetermined warranty or guarantee period are offered an annual maintenance contract by the company or their service vendor.

Most filters have a purification unit that needs periodic replacement. While with the more sophisticated models the company replaces them, the low cost models have replacements that are available over the counter. Once the indicator goes off, the user can buy the unit and replace it at their own homes.

- **Disposal**

A key aspect in the life cycle is the disposal. This is generally not accorded enough importance by any of the stakeholders in the supply chain. At the consumer end, disposal comes in at two points i.e. the replaceable purification unit at periodic intervals and the shell of the unit at the end of it’s shelf life. While most companies are silent on the appropriate mechanism, some advocate disposing of the waste along with solid waste. This waste then either reaches landfills or incinerators.

Appropriate disposal assumes even more importance in the case of nano technology based products as the impacts of leaching are still not adequately explored. The impact on land and environment as well as bio-accumulation and bio-magnification through the food chain are potential hazards. This ties in with the level of disclosure to the user on these aspects.

Certain ideas put forth to avoid this include allowing purchase of a new candle only on returning the used one or offering a discount on returning used candles. This would ensure that they are appropriately disposed and the silver is recovered. There is also a need to reduce the non-biodegradable components minimizing the recycling and recovery pressure.

The Xerox Corporation demonstrated early on that remanufacturing can be a very lucrative prospect. In 1991, they obtained savings of around $200 million by remanufacturing copiers returned at the expiration of their lease contracts. The Global Asset Recovery Solutions division of IBM collected over one million units of used information technology (IT) equipment that was converted to billions of dollars in revenues on the second hand equipment, parts and materials markets.

Recycling

There is an option of recycling certain parts of the unit. This has obvious environmental benefits in terms of less waste generated and reduced energy consumption as well as economic benefits. Despite all of these benefits from remanufacturing, most firms continue to either ignore, or in some cases, actively try to deter, any remanufacturing and reuse of their products. There are very few industries where all of the major companies in that industry participate in remanufacturing or product take-back initiatives at the same level of effort.

The products made up of single material are of relatively easy to recycle into new products than the complex materials which require additional dismantling. Collection of disposed units becomes a challenge for recycling. Brita[6] started a “Take Back” campaign in collaboration with Preserve, a U.S. based company that manufactures household products from recycled plastic, to recycle 100% of the plastic casing of the filter. The filter material will be regenerated or converted to energy. Collection of disposed units was facilitated by establishing drop off points at Whole Food Markets. Users could also mail them directly to the company.

- **Disclosure**

Disclosure of information is very important in order to educate the customer about the technology, its pros and cons, the losses with the current system and the benefits of implementing the new system. However disclosure levels in the sector and the country are very low. While features of the product are shared, information on replacement and

6 http://www.brita.com/your-brita/recycle-your-filter/

subsequent disposal is perfunctory. Even when units contain nano materials, no special disposal mechanisms have been set into place. Also no follow up or monitoring systems are in place to ensure that the discarded materials reach their designated spaces.

This lack of disclosure is not only at the consumer level. It was observed that this is persistent along the supply chain between the production facility and the distribution and retail centers. While comparing the information disclosed here, in India, with the other countries like in USA[7] a water purifiers website discloses: Purification process, its benefits, comparison with other products, how it saves waste, effect of chlorinated water on different parts of the body, a video on how the mechanism of water purification works, how it is saving the minerals present in water and the effects of loss of these minerals from water on the body in the long run, product specifications, operating parameters.

- **Risk management**

Nanotechnology-based applications will substantially improve the performance of many products through the unique properties of engineered nano materials. The same properties, however, raise questions as everything about these materials is not known. Nanotechnology is a relatively new field of study and its side-effects, if any, are not known. So, going with the precautionary principle we will be looking sequentially at every stakeholder's role in handling nano materials in terms of the practices that should be followed and if they are being done.

Risk management should become an integral part of the culture of the organizations involved in the making the product reach the market. There are certain good practices and guidelines followed in some countries[8]. These are highlighted at the Laboratory level and production facility and transportation.

- A Standard Operating Procedure (SOP) for operations involving nano-materials should be strictly followed by everyone involved in the process.
- Researchers and workers should have both general safety training and lab-specific training relevant to the nano-materials and associated hazardous chemicals used in the process/experiment.

7 http://www.waterfilter-usa.com/pelican-pc600-premium-whole-house-water-filter-13-bathrooms-p-267.html

8 http://www.stanford.edu/dept/EHS/prod/researchlab/IH/nano/lab_safety_guidelines.html

- Researchers and workers should use adequate personal protective gear and safety features in the laboratory. Also many researchers specified keeping risks at a minimum by keeping nano materials in liquid phase rather than gaseous.
- The storage containers and facilities need to be well-sealed and properly labeled and in case of any dangerous material caution should be shown. Similar care to be taken during transport of these materials.

4. Conclusion

The study highlighted certain lacunae in the current systems. Key among these were the lack of stress on risk management and the poor disclosure norms.

Given the potential hazards that may arise during the life cycle particularly disposal of nano based units, risk management becomes a very important step. Also given the large range of stakeholders handling the unit, it is very important to have adequate and appropriate information flow between the various stakeholders.

These learnings will feed into the design of the delivery model for the pilot. Also lessons from the innovative approaches already implemented will be adapted to suit the context of technology and location.

5. Annexures

5.1 Annexure 1: Technologies in the Market

TATA Swach[9] is a product of Tata chemicals Ltd. The Tata Swach was designed by Tata Research, Development and Design Centre (TRDDC) and Tata Chemicals with contributions from other Tata group companies. In 2004 the company developed a water purifier called "Sujal". Tata Consultancy Services deployed thousands of these filters in the Indian Ocean Tsunami disaster of 2004 as part of its relief activities.

The Sujal was a very basic low-cost model which used rice-husk ash (produced from heating rice husk in combination with pebbles and cement). Activated silica and carbon is present in the ash; silica can reduce the turbidity of water, while activated carbon binds with and adsorbs non-polar impurities (such as pesticides and fertilizers). However, the purification system did not have bacteriostatic or bactericidal properties and it was incapable of removing impurities such as lithium, alcohols, ammonia, strong acids and bases or inorganic substances like sodium, lead, iron, arsenic and nitrates. Dr. Muraly Sastry, Chief Scientific Officer of Tata Chemicals, confirmed that even though Sujal could successfully remove the odour, colour and particulate matter from impure water, many pathogens could not be eliminated. Now, they have come up with the same product with the name of TATA Swach.

It works on the TSRF technology: In the Tata Swach design, water purification is carried out using processed rice husk ash impregnated with nano (1 x 10-9) silver particles for purifying the water and to destroy disease causing bacteria, germs and other organisms. The bacteriostatic and bactericidal properties of silver is attributed to its ability to react with the sulfhydryl (-SH) groups in the bacterial cells that produces the structural changes in bacterial cell membranes and interacts with nucleic acids. The nano sized particles help in increasing the surface area so that the bacteria get enough reaction time.

ata Swach Bulb is the main purifying unit of the product. The Swach Bulb, depending on the quality of water, can purify about 3000 litres of water, after which the bulb must be replaced. The bulb has a "fuse" indicating when a cartridge change is required.

HUL Pureit is a range of water purifiers made by Hindustan Unilever currently sold in India, Mexico, Brazil, Srilanka, Nigeria, Indonesia and Bangladesh, consisting of six models: Pureit Classic, Pureit Compact, Pureit Classic Autofill, Pureit Intella, Pureit Marvella and Pureit

9 http://en.wikipedia.org/wiki/Tata_Swach

Marvella RO. Pureit was first launched in Chennai in 2004. Pureit claims to meet the E.P.A. germ-kill criteria.

Purification process[10]: Pureit is the world's most advanced in-home water purification system. Pureit purifies your drinking water in four stages and removes visible dirt, pesticides, harmful parasites, viruses, bacteria and residual chlorine to make water clear, odorless and natural tasting. Pureit consists of four parts that purify the water in four stages: a 'microfibre mesh', a 'compact carbon trap', a 'germkill processor' and a 'polisher', as branded by Hindustan Unilever. The microfibre mesh functions as a sieve, filtering out visible dirt. The carbon trap removes parasites and pesticides. The processor is a tablet consisting of chlorine. This stage removes bacteria and viruses. The polisher improves taste and clarity of water and removes the residual form of chlorine from the water. These four parts are collectively branded the germkill kit or the battery.

This battery needs continual replacing, as indicated by a germkill battery indicator visible on the front of the device. The germkill kit is designed to work at 25° C in moderately humid conditions. The volume specified by the germkill battery assumes these conditions. The germkill kit has an expiry date of three years from the date of packaging.

The output water from Pureit meets stringent criteria for microbiologically safe drinking water, from one of the toughest regulatory agencies the USA, EPA (Environmental Protection Agency).

Aquaguard Total Infiniti[11]: Aquaguard Total Infiniti is equipped with a thorough multi-stage purification process, including Intell-e-boiling+ which ensures that water from Aquaguard Total Infiniti is as safe and as pure as water boiled for 20 minutes. The purification process happens in various steps:

First the water passed through the Clarity Cartridge, which strains out the physical impurities present giving clean water which then passes through the patented Active Silver+ Cartridge which absorbs the color, odour, organic impurities, excess chlorine, pesticides etc. and also prevents further microbial growth. The water then passes through the patented surround purity system where it receives a surround dose of e-boiling. This eliminates all disease causing bacteria, virus, protozoa and cyst with Mineral Preserver System which provides absolutely pure and healthy drinking water. Also, there is Intelligent Purity Sensor which scans the water

10 http://www.pureitwater.com/IN/pureit-technology

11 http://www.eurekaforbes.com/products/UserManual/Aquaguard_INFINITI_UserManual.pdf

and if any impurities are found it automatically shuts-off the water supply ensuring the supply of absolutely safe or no drinking water.

ARCI Candle: It was an effort of Dr. Tata Narasingma Rao of ARCI. He made normal ceramic candle coated with Nano silver with anti-microbial action. The amount of silver used in one candle is approximately equal to 0.5 grams. When the water passes through the candle the bacteria comes in contact with the Nano silver particles and gets destroyed. Mr. Rao had a contract with the local company SBP Aquatech Pvt. Ltd. Who have the exclusive rights for Chennai. The cost of the candle is Rs.130 approximately but may be due to the bad marketing strategies the demand for the candle was very low because of which the production had to be stopped.

Vestergaard Lifestraw Family: It was developed by Vestergaard Frandson which is a Europe-based international company specializing in complex emergency response and disease control products. When untreated water is poured into the feed water bucket, the textile prefilter removes coarse particles larger than 80µm. Gravity pushes the water with particles finer than 80µm to flow down the plastic hose towards the purification cartridge. The purification cartridge, which contains an ultra filtration (hollow-fiber) membrane of 20nm porosity, stops all particles larger than 20nm (including all microbes: protozoan parasites, bacteria and viruses). Turbidity particles are also stopped by the membrane by size exclusion. The untreated water is pushed through the ultra filtration (hollow-fiber) membrane by gravity, i.e. by the pressure applied by the 1m long plastic hose, which corresponds to 0.1 bar pressure. This 0.1 bar pressure forces the water through the pores of the hollow-fiber membrane; particles and microbes larger than 20nm stay on the dirty side of the membrane and clean/purified water passes through the membrane. Purified water can be collected from the blue tap. When the cleaning bulb is squeezed, dirt particles on the dirty side of the membrane are lifted by backpressure and then removed.

Filters up to 18,000 litres of water, enough to supply a family of five with microbiologically clean drinking water for three years, thus removing the need for repeat intervention Ensures high flow rate and high volume of purified water Complies with US Environmental Protection Agency 1987 Guide Standard and Protocol for Testing. It Removes turbidity, and minimum 99.9% of protozoan parasites, bacteria, viruses. It Requires no electrical power, batteries or replacement parts as well as no running water or piped-in water supply. It has an easy-to-clean pre-filter and purification cartridge. All raw materials are US Food and Drug Administration compliant or equivalent.

The Tulip Siphon Water filter: Basic water Needs is an Netherlands based company with the aim of developing low cost water filter has brought Tulip Siphon in the market. In 2008 this filter has been introduced in India Basic Water Needs India Pvt. Ltd in south India. They had collaborated with Bajaj to promote this filter in India which could not take of as per expectation of the company. Now company considers this water filters should be promoted through NGO and finished agreement with Bajaj in India. Apart from India filter is used in fifteen other countries internationally.

Filter works on gravity siphon pressure principle to force water through silver impregnated ceramic filter. Silver impregnated ceramic candle is the main water cleaning part of the filter. The innovative usages of the siphon results in high flow rate of 4-5 liters per hour of bacteria free water. Filter looks quite compact as only elements are filter element, a plastic hose, and a valve, while any storage containers can be used. As per the manufacturer specialty of the product is, it leaches around 3 to 6 ppb of residual silver in the treated water to prevent risk of bacterial recontamination during its storage. This residual silver content is below the permissible level. Filter provides about 7000 liter of bacterial safe water subject to appropriate turbidity (not mentioned in manual). Bacterial removal efficiency is claimed around 99.99%. Filter is equipped with effective life gauge indicator to inform about replacement of silver impregnated ceramic candle. Cost of the filter is Rs215/- and replaceable candle cost is Rs95/- Availability of the filter is limited to few places mostly with manufacturer. Major attraction in the filter is its low price. Also, residual silver in pure water gives an additional cover for bacterial recontamination. Counting on these merits this Tulip filter has prospects to try out in one of our delivery model.

5.2 Annexure 2: Technologies in the Research Phase

Stanford University: A plain cotton cloth dipped in a high-tech broth full of silver Nano-wires and carbon Nano-tubes, a high-speed and low cost filter has been developed that could easily purify water.

Instead of trapping the bacteria it lets it pass through and bacteria is killed by the electric field that runs through the highly conductive “Nano-coated” cotton. Since the new filter doesn't trap bacteria, it can have much larger pores, allowing water to speed through at a more rapid rate which is claimed to be around 80,000 times faster than the already present filters. The larger pore spaces in this newly designed also keep it from getting clogged, which is a problem with filters that physically pull bacteria out of the water.

The objective was to make the filter cost effective so negligible amount of silver Nano-wires is used and due to the required qualities of the foundation material ordinary woven cotton is dipped into a solution of carbon Nano-tubes and then it is left to dry and after that it is dipped into carbon nanowire solution.

The electrical current that helps do the killing is only a few milliamperes strong – barely enough to cause a tingling sensation in a person. The low electricity requirement of the new filter is another advantage over those that physically filter bacteria, which use electric pumps to force water through their tiny pores. Those pumps take a lot of electricity to operate.

The pores in the Nano-filter are large enough that no pumping is needed – the force of gravity is enough to send the water speeding through. Although the new filter is designed to let bacteria pass through, an added advantage of using the silver Nano-wire is that if any bacteria were to linger, the silver would likely kill it. This avoids bio-fouling, in which bacteria form a film on a filter. Bio-fouling is a common problem in filters that use small pores to filter out bacteria.

The next steps in the research are to try the filter on different types of bacteria and to run tests using several successive filters.

Aberdeen University: In order to address the need of safe water for a cost effective way to provide this, scientists at the University of Aberdeen had been developing a new technology that uses a sunlight-powered catalyst to treat contaminated water. The photo electro-catalyst is mounted into an electrochemical cell and, when it reacts to light, the catalyst interacts with any organic pollutants in the water, oxidizing them across the catalyst’s surface. Another by-product of this process is the recovery of charge in the cell, meaning that as well as purifying water, this technology also creates electricity.

The objective is to build a working prototype in order to demonstrate that the technology is commercially viable within the water supply industry. This will require close integration with manufacturing partners to ensure that the laboratory models are successfully scaled up, that the correct materials are selected and to consider issues such as position and orientation of components. However, before the prototype can be built, the technology has to be tested and adapted to ensure it meets its end-users' needs

Stellenbosch University: Prof. Eugene Cloete and his colleagues at the Water Institute of the University of Stellenbosch have come up with an inexpensive, teabag-like sac of Nano-fibres - each about one hundredth the width of a human hair — which is secured into the lid of a reusable vessel. The water then passes through the filter secured in the lid and is thereby purified and made much more potable for human consumption.

The inside of the tea bag material is coated with a thin film of biocides encapsulated within minute Nano-fibres to kill all disease-causing microbes and filled with active carbon granules that remove all harmful chemicals. Each "tea bag" filter can clean one litre of the most polluted water to the point where it is 100% safe to drink. The filter cannot desalinate the water nor can it clean acid mine drainage. It is most suitable for cleaning running river water in rural areas where there is no contamination from heavy industrial development and direct disposal of untreated sewerage. The highlight of this invention is its cheapness. Its estimated cost of purifying water is half a U.S. Dollar cent.

Over the past few months, the research team at Stellenbosch University has been kept busy with the painstaking task to upscale the laboratory prototype to ensure that it is ready for the full production phase and that it meets all the necessary criteria. The necessary funding is now in place to support the important development work needed to turn the idea of the filter into practical reality.

Stellenbosch University has now entered into a license agreement with the company that holds the exclusive license to manufacture market and distribute the teabag water filter. It will pay royalties to the University.

In **Indian Institute of Technology, Bombay** there is a lot of research going on in the field of Nanotechnology that can be further used in water purification. Nanotechnology based devices use a fraction of energy as compared to reverse osmosis (RO) or distillation method to desalinate the seawater. In IIT Bombay research on surface engineered nano particles for the detection and separation of toxic metal and organic dyes in being done. Dr. Dhiren Bahadur with some colleagues is working on removing toxic metal ions (Cr^{3+}, Ni^{2+}, Co^{2+}, Cu^{2+}, Cd^{2+},

Ag^{+}, Hg^{2+}, Pb^{2+} and As^{3+}) and microorganisms (Escherichia coli(E. coli), Sarcinalutea (S. lutea) and Staphylococcus aureus (S. aureus)) from waste water. Adsorption is conventional but most effective technique to remove toxic ions and bacterial pathogens from water. Recently, magnetic Nanoparticles (MNP) such as Fe_3O_4 and gamma-Fe_2O_3 have been investigated to resolve various environmental problems, such as removing toxic metal ions and radioactive elements, capturing of microbial pathogens and organic dyes, accelerating the coagulation of sewage, and remediation of contaminated soils [9–13]. The magnetic nanoparticles possess high surface area and optimal magnetic properties, which lead to high adsorption efficiency, high removal rate of contaminants, and easy and rapid separation of adsorbent from solution via magnetic field. The magnetic nanoparticles can be reusable after magnetic separation by removing the adsorbed toxic contaminants. Furthermore, magnetic nanoparticles functionalized with bio recognition molecules such as antibody, bioprotein and carbohydrates or biocompatible organic/inorganic molecule, polymers and dendrimers are more effective since the free functional groups present on the surface provide large number of active sites as well as aqueous stability, which is necessary for the successful adsorption of toxic metal ions and bacterial pathogens. In order to achieve this, new and effective aqueous stabilized surface engineered/surface functionalized magnetic nanoparticles with low regeneration cost are needed. However, the research in this area is in its nascent stage and detail investigations are required to establish the large scale purification of water in real life.

IIT-Chennai: Noble metals are historically known to be extremely non-reactive. This is understood from a number of facts: unusually high reduction potential, high ionization energy, high melting point, relativistic contraction etc. A number of such properties have dependence on size of the particle like, small size particles leads to an increase in specific area, increase in surface energies for easier dislocation of electrons and perfection in atomic organization in the lattice. The new found roles of noble metals as an efficient catalyst are increasingly being utilized for drinking water purification. Amongst all the recently developed nano-adsorbents for drinking water purification, the chemistry of noble metal nanoparticle is unique. The chemistry of silver nanoparticles has been utilized to remove a number of toxic contaminants found in drinking water including pesticides, heavy metals and micro-organisms. The advantages of silver nano particles and other nano-base adsorbents are the stability of silver nanoparticles against surface oxidation, complete degradation of pesticides, removal of heavy metals in high proportions and broad range anti-microbial action. These capabilities associated with silver nanoparticles make them effective nano-adsorbent for removal of toxicity in the water and also a potential area for the research.