# R&D Activities related to Arsenic Contamination in Drinking Water

*Salient Efforts of Department of Science and Technology (DST)*

**JUNE 2015**

सचिव
भारत सरकार
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## *Foreword*

For treatment of Arsenic, the two key research challenges are development of cost effective efficient materials, processes & systems and development of cost effective reliable field kits capable of measuring arsenic content at trace level.

Department of Science and Technology (DST) has focused its R&D activities on removal of Arsenic from drinking water to make it potable. Right from the development, encapsulation and stabilisation of materials to the development of processes and systems, attempts have been made to modify locally available materials for improved removal efficiency at lower cost. Nano-technology has also been used for developing more efficient sensing and removal of Arsenic. The alternatives to chemical oxidants and newer materials superior to conventionally used adsorbents (such as activated alumina) were identified/ developed. Processes generating less sludge were promoted and household filters were encouraged with the participation of village panchayat/ municipal authorities to ensure responsible sludge management. The concerted efforts of the Department have succeeded in demonstrating potential of technologies developed to provide potable water at reasonable cost to public.

DST through its vast network of researchers nationally and forging collaboration globally strives to continuously make appropriate technology systems available to address the various research challenges in more effective and efficient manner. DST also supports line departments in making independent assessment of appropriateness of technologies to specific social context to ensure their sustainability.

It is hoped that information provided in this compendium would provide useful technological leads to various stakeholders and showcase the commendable effort made by the scientific community in service of society.

(Ashutosh Sharma)

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# 1. Technology based Solutions for addressing Water Challenges

Department of Science and Technology, realising the need to address various Research and Development (R&D) issues in providing safe water, launched Water Technology Initiative (WTI) in the year 2007-08, with an aim to design and develop low cost solutions for domestic use of safe drinking water, referencing of technologies to social context, capacity building of water managers and encouraging new research ideas.

In order to develop holistic and viable research and technology based solutions for tackling problems of water quality and water scarcity, the Department promoted activities so as to address issues related to drinking water in terms of purification, availability, reuse and recycling under the aegis of Technology Mission "Winning, Augmentation and Renovation (WAR) for Water".

A Technical Expert Committee (TEC) constituted by the Government of India (GoI), identified 26 major water challenges prevalent in the country. One of these challenges was geogenic contamination due to Arsenic (As).

## 2. R&D Activities on Arsenic Contamination in Drinking Water

The R&D activities promoted by the department focused primarily on the issues related to detecting the presence of Arsenic and removal of Arsenic from the drinking water. The R&D challenges identified by the department included.

i. Development of cost effective detection techniques with technical performance better or comparable to currently available alternatives
ii. Development of cost effective and efficient materials for Arsenic removal based on locally available resources.
iii. Development of household and community Arsenic removal systems based on indigenously developed materials
iv. Field demonstration of developed systems to assess their suitability in specific social context.
v. Sludge management.

The objective of the R&D activities was to develop adsorbents which were cheaper yet efficient for removal of Arsenic from drinking water. Various types of adsorbents were prepared and their loading capacity was compared with other alternatives. Attempts were made to develop adsorbents superior to commercially available adsorbents for a wide range of operating conditions i.e. pH & temperature, having larger surface area and higher adsorption capacity. Further, suitable encapsulation and stabilization of the developed material through appropriate techniques was undertaken to enable their prolonged use with least adverse effect on the efficiency.

Considering the fact that Arsenic (III) removal was quite difficult, efforts were also made to develop improved oxidation methods besides chemical oxidant for faster conversion of Arsenic (III) to Arsenic (V). Recognising the importance of developing low cost detection techniques for estimation of Arsenic in ground water, efforts were made to develop cost effective field test kits having shelf life, detector strip sensitivity, incubation time and interference due to presence of other contaminants, better than or at least comparable to commercially available imported test kits.

The promising leads obtained from the investigations of various materials were taken to the next logical steps which focused on lab scale studies of these materials for spiked as well as naturally contaminated Arsenic laden water.

The successful lab scale systems were upscaled and prototypes were tested in real field conditions. The systems which conformed to technical performance parameters and found large community acceptance were replicated in larger numbers to generate enough scientific data for validation.

Several R&D projects, involving water treatment systems/ processes, devices, materials, etc., for providing safe and adequate drinking water have been initiated. The department has so far supported around 25 R&D projects at a total cost of Rs 675 lakh.

## 3. ***Projects Supported by DST to address Arsenic Contamination***

| Project Title<br><br>PI Name & Institution Address | Achievements |
|---|---|
| AMRIT- Arsenic and Metal Removal by Indian Technology<br><br>Prof T. Pradeep,<br>Professor,<br>DST Unit of Nanoscience and Thematic Unit of Excellence on Clean Water, Department of Chemistry<br>Indian Institute of Technology Madras, Chennai 600 036 | ❖ *Affordable, compact, gravity-fed water purification unit for providing clean drinking water in arsenic affected areas in which Arsenic and Iron containing water is passed through a composite filter unit to obtain water, conforming to international standards.*<br>❖ *Implemented at various levels - homes, small communities and large scale water supply programs.*<br>❖ *200 household units demonstrated in Yadgiri District of Karnataka and Murshidabad district of West Bengal*<br>❖ *160 units of community filter demonstrated in Villages spread across the districts of Murshidabad and Nadia, (West Bengal)*<br>❖ *The design is inspired from a coconut thus making the innovation scientifically unique, green and sustainable.*<br>❖ *All materials and technologies are patented. Over 35 Indian/PCT patents have been filed.*<br>❖ *Arsenic Task Force of West Bengal government certified and approved the purifier* |
| Development of low cost household filter for arsenic and other pollutant-free drinking water using modified laterite.<br><br>Field trial of low cost laterite based Arsenic filter: Domestic and community scale<br><br>Prof. Sirshendu De, Professor,<br>Department of Chemical Engineering,<br>Indian Institute of Technology, Kharagpur-721302 | ❖ Development of efficient modified laterite adsorbent<br>❖ Design and installation of arsenic filter for domestic (120 L/day) and community (500 L/day) scale integrated with alum dosing to remove iron and bacterio-static carbon to remove coliform.<br>❖ Evaluation of 10 domestic filter and 1 community filter revealed successful performance. |
| Implementation of Cost Effective Household Arsenic Remediation Technology in West Bengal.<br><br>Demonstration of Cost-Effective and indigenous Domestic Arsenic Remediation Technology for Arsenic Mitigation in Arsenic affected areas of India<br><br>Dr Pahari Basu, PI, Save the Environment,<br>Kailash Ghosh Road, Kolkatta- 700 008 | ❖ Technology sourced from Naval Materials Research Laboratory (NMRL) Ambernath (DRDO).<br>❖ Design is cost effective, requires no power, environment friendly, easy to maintain & operate<br>❖ Utilisation of locally available processed waste of Steel Industry for co-precipitation of Arsenic with Iron.<br>❖ Demonstrated in 24 Paraganas (North) of West Bengal. 250 Arsenic removal filters were installed in the village Lalmath situated in Nadia district, benefitting 1250 vilagers. |

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| Laboratory based studies on the evaluation of cost effective adsorbents for Arsenic filter units<br><br>Dr. Nalini Sankararamakrishnan, Facility for Ecological and Analytical testing, Indian Institute of Technology, Kanpur-208 016 | ❖ Development of Iron oxide coated/ Iron doped chitosan adsorbent<br>❖ Design of domestic filter<br>❖ Field studies on Arsenic contaminated ground water,<br>❖ Analysis of the sludge and leaching test for used adsorbent |
| Development of Arsenic adsorbing polymeric beads and their performance study in packed bed columns<br><br>Development of prototype systems to produce Arsenic-free safe drinking water<br><br>Prof. Priyabrata Sarkar, Department of Polymer Science and Technology, University of Calcutta, 92 A.P.C. Road, Kolkata | ❖ High capacity Arsenic adsorbing beads (17.5 mg/g of Arsenic V) based on synthesised nano- alumina dispersed in chitosan grafted poly-acrylamide.<br>❖ Development of ceramic filter candle containing adsorbents immobilized/ micro encapsulated in polymer matrix for removal of Arsenic from drinking water<br>❖ Interference and optimisation studies required to assess suitability for field use. |
| Field Application and Management of community based Arsenic Removal units in Rural Areas of West Bengal<br><br>Dr. Asis Mazumdar,<br>School of water resource engineering, Jadavpur University 188 Raja S.C. Mulik Road,West Bengal-700032 | ❖ Field model (800-1000 lt / hr) based on co-precipitation, adsorption and filtration mechanism developed for Arsenic removal.<br>❖ Handpumps attached units demonstrated at 3 locations, each benefiting around 50 families.<br>❖ Unit does not require to be operated under pressure.<br>❖ Possibility of upscaling for higher capacity |
| Field Test Kit for Arsenic in Water<br><br>Prof. Priyabrata Sarkar, Department of Polymer Science & Technology, University of Calcutta, 92 A.P.C. Road, West Bengal, Kolkata | Mercuric bromide and silver nitrate detector element low cost kit for total arsenic and arsenate,<br><br>❖ Colorimetric sensor for ppb level arsenic contamination in drinking water.<br>❖ Dip Stick colorimetric sensor for detection of arsenate in drinking water. |
| Continuous Arsenic Removal Using Zero-valent Iron Filter (ARUZIF) from Drinking Water<br><br>Development of continuous mode arsenic removal technology for drinking water based on indigenous Zero Valent Iron<br><br>Dr Sanjeev Chaudhari,<br>Professor , Center for Environmental, Science and Engineering, Indian Institute of Technology, Bombay, Mumbai- 400 076 | ❖ Development of a simple process that uses indigenous Zero Valent Iron (ZVI) and a specially designed unit (which ensures good oxygen transfer, separation of Hydrous Ferric Oxide (HFO) flocs and uses locally available low cost granular media) for arsenic removal from drinking water.<br>❖ Two of these units are operating at a flow rate of 600 litres per hour in villages of West Bengal from February 2008.<br>❖ 46 more such units have been installed in various parts of Uttar Pradesh, Bihar, West Bengal and Assam. |

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| Development of clay-based biosorbents for purification of water contaminated with arsenic, iron and fluoride<br><br>Dr. Krishna Gopal Bhattacharya, Professor, Department of Chemistry, Gauhati University, Guwahati 781014 | ❖ Development of novel material for low cost removal of various contaminants including Arsenic.<br>❖ Feasibility of biosorbents for adsorption being studied. |
| A Comprehensive study of presence of Arsenic in the underground drinking water in Punjab<br><br>Dr. Umesh K. Garg, Assistant Professor, Department of Applied Science, Adesh Institute of Engineering & Technology, Sadiq Road, Faridkot – 151203 Punjab | ❖ Assessment of arsenic in Malwa region of Punjab (Bathinda, Faridkot, Firozpur, Muktasar, Sangrur).<br><br>❖ Around 50% samples Arsenic contaminated |
| Synthesis and characterization of gold nano particles for arsenic detection<br><br>Prof. Mulayam Singh Gaur, Professor & Head, Department of Physics, Hindustan College of Science & Technology, Farah, Mathura – 281122, Uttar Pradesh | ❖ Exploratory study for utilisation of Nano particles for detection of Arsenic |
| Assessment of Arsenic and other contamination in potable Water in cities of Mizoram<br><br>Dr. Shiva Kumar, Associate Professor, Mizoram University, Tanhril Permanent Campus, Aizawl – 796 004, Mizoram | ❖ Crystalline rock of Myanmar have tendency to contain toxic material such as arsenic<br>❖ The main river providing potable Water to Aizawl originates from crystalline rocks of Myanmar.<br>❖ To generate baseline data about arsenic prevalence in Aizawl area. |
| Development of ceramic membrane based contactor for enhanced arsenic and iron oxidation for potential application in arsenic and iron removal plants<br><br>Mr. Swachchha Majumdar, Central Glass & Ceramic Research Institute, 196, Raja S.C Mullick Road, Jadavpur, Kolkata – 32 | ❖ Improved method for faster conversion of Arsenic III to Arsenic V using ceramic membrane based contactor. |
| Development of plant prototype for removal of ammonia, arsenic and odorous compounds from water/ wastewater by ozone micro-bubbles<br><br>Dr. Pallab Ghosh, Associate Professor, Indian Institute of Guwahati, Guwahati – 781 039, | ❖ Development and characterization of Zirconium based adsorbents<br>❖ Development of a new process using ozone micro bubbles for Ammonia and Arsenic removal from waste water. |

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| Formulation and validation of Arsenic removal studies from contaminated drinking water<br><br>Dr. R.K. Sharma, President, Durga Sewa sadan, 101, Sushila Vihar- I, Bhur, Bulandshahr – 203001, UP | ❖ Study on efficacy of various Arsenic removal processes |
| Design consideration and field performance validation of high arsenic removal water filter packed with lab-bench developed materials: A lab-to-field technology transfer programme"<br><br>Dr. S. Chakrabarti,<br>Presidency University, Kolkata. | ❖ Synthesis of cost effective non hazardous Manganese incorporated Ferric oxide (MnFO)<br>❖ Arsenic removal using synthesized nanoparticles of MnFO<br>❖ Efficiency in removal of high Arsenic, Nitrate, Chloride, Phosphate contaminated water established.<br>❖ Sludge analysis indicates non hazardous nature of adsorbent |
| Ion-specific resins and membrane based systems/ processes to bring the level of Arsenic to WHO limits in drinking water<br><br>Dr. K.M. Popat,<br>CSMCRI, Bhavnagar, Gujarat | ❖ Pre-treatment of Arsenic contaminated water and removal of Arsenic by Reverse Osmosis (RO) process.<br>❖ Utilisation of sludge as bricks and ensuring no Arsenic leached out from these bricks<br>❖ Mercuric Bromide coated test strips developed for sensitivity upto 25 ppb.<br>❖ Use of indigenously developed Arsenic specific resin for final polishing of water. |
| E-tongue based detection and estimation of Arsenic in contaminated $H_2O$<br><br>Dr. Madhusree Kundu,<br>National Institute of Technology, Rourkela. | ❖ Novel potentiometric sensor combined with signal processing and pattern recognition for high specificity through extraction of suitable features and authentication based on extracted features.<br>❖ Project underway |
| Low cost technology for purification of Arsenic and microbes contaminated water using nanotechnology<br><br>Dr. (Mrs) Vijaya Agarwala, IIT Roorkee and National Institute of Hyderabad, Roorkee. | ❖ Use of magnetite and silver zinc oxide nano composites in the pores of charcoal for removal of Arsenic<br>❖ Project underway |
| Removal of Arsenic from drinking water using liquid membrane based separation technique<br><br>Dr. Prabir Kumar Saha, Professor,<br>Indian Institute of Guwahati, Guwahati | ❖ Identification of low cost, easily available and environmentally benign solvent (vegetable oil etc) to extract Arsenic (solute)<br>❖ Study of separation process in continuous mode employing hollow fibre membrane and flat sheet membrane |

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| Integrated technology for the removal of Arsenic from ground water<br><br>Field scale trials of the ARI, Pune technology for the removal of arsenic from drinking water in Rajnandgaon District of Chhattisgarh.<br><br>Dr. K.M. Paknikar, Scientist,<br>Agarkar Research Institute, Pune | ❖ *Microbacterium lacticum* can oxidize arsenite (As3+) in groundwater rapidly to arsenate (As5+).<br>❖ Developed a unique 'integrated microbial oxidation alumina adsorption process for the removal of arsenic from groundwater rendering it completely safe.<br>❖ Feasibility on applicability of flat sheet liquid membrane based separation process for removal of Arsenic from groundwater. |
| Removal of Arsenic from drinking water using polymeric membranes.<br><br>Development of a low cost adsorbent (Hydrogen Ferric Oxide) and household model for removal of Arsenic from underground water.<br><br>Dr. U.K. Kharul and Dr. G.P. Aggarwal, NCL, Pune & IIT Delhi, Hauz Khas,Delhi | ❖ Development of low pressure ultra filtration (UF) membrane process for effective and selective removal of Arsenic (As-V).<br>❖ Aplicability of polyacrylonitrate (PAN) based negetively charged UF membrane for effective Arsenic removal.<br>❖ Membranes did not foul, worked for long and rejected 100% arsenic. However, efficacy reduced in the presence of Phosphate, Sulphate, Carbonate etc. |
| Development of multichannel ceramic membranes with optimum channel configuration for up scaling the technology for purification of Arsenic contamination ground water.<br><br>Dr. S. Bandyopadhyay, Scientist, Central Glass & Ceramic Research Institute, 196 Raja S.C. Mullick Road, Jadavpur, Kolkata 32 | ❖ Hybrid process using suspended adsorption media and cross flow micro-filtration for decontamination of Arsenic.<br>❖ Optimum Channel Configuration (Circular and Star) for minimising fouling of membrane surface. |
| Integrated Arsenic and Iron removal from contaminated ground water<br><br>Dr. Robin Kumar Dutta, Department of Chemical Sciences, Tezpur University, Napaam, Tezpur, Assam. | ❖ Development of a method based on oxidation-coagulation at optimum pH.<br>❖ Removes As as well as Fe from contaminated groundwater to below the WHO guideline levels of 10 ppb and 0.3 ppm, respectively.<br>❖ Technique uses three common chemicals, viz., baking soda ($NaHCO_3$) for pH conditioning, $KMnO_4$ for oxidizing As(III) to As(V) and Fe(II) to Fe(III), and $FeCl_3$ for coagulation and adsorption of As.<br>❖ The cost of material is less than 1 paise per liter of water. It is also user-friendly and works without electricity. |

# 4. *Product Description of Select Projects supported by DST*

## *4.1. Laterite based Arsenic Filter by Indian Institute of Technology- Kharagpur*

The Laterite based Arsenic filter uses naturally abundant raw laterite modified by suitable chemical treatment. It requires no power for functioning. The adsorbent is cost effective and adsorbs both As (III) and As (V). The salient features of this filter are:

- Laterite based arsenic filter is designed and fabricated for domestic and community scale.
- Removal capacity of Arsenic (total) is 32.5 mg/g. This is maximum among other Arsenic adsorbent materials such as expensive activated alumina, iron oxide coated sand, iron based commercial adsorbent etc.
- Arsenic concentration in filtrate is within the WHO permissible limit for drinking water (10 ppb)
- Raw, naturally abundant laterite (commonly known as MORAM) is modified using suitable chemical treatment (acid-alkali treatment).
- No power requirement for domestic filters.
- Removal of iron, arsenic and bacteria using the same filter.
- The filter removes Iron below permissible limit in drinking water (1 ppm) and more than 98% of pathogenic contaminants.
- No regeneration of adsorbent (filter medium) is required
- Alum dosing is done (15 mg/l) to remove iron.
- Leaching does not occur from the spent Laterite (adsorbent meets TCLP protocol)
- The capacity of domestic filter is in the range of 40-120 litres/day and for community scale it is in the range of 500-2000 litres/day. These units are scalable as well
- The filter bed consists of different layer of materials including bacteriostatic activated carbon, charcoal, fine granular sand, activated laterite and raw laterite.
- A layer of bacteriostatic carbon is employed to remove coliform successfully.

| *SN* | *Features* | *Description* | |
|---|---|---|---|
| 1 | **Product Definition**<br>**a. Product Name** | Low cost Laterite based Arsenic Filter | |
| | **b. Type of Product** | *Domestic and Community Filter* | |
| | **c. Cost of Unit** | ***Domestic:*** *Rs. 2500* | ***Community:*** *Rs 15000 for 100 lph* |
| | **d. Capacity of the Unit** | ***Domestic:*** 40-120 litres/day | ***Community:*** 500-2000 litres/day |
| | **e. Technology Used** | ***Domestic:*** *Single stage- Adsorption* | ***Community:*** *Double stage- Sedimentation, Adsorption* |
| | **f. Flow rate** | ***Domestic:*** *4-5 lph* | ***Community:*** *100-2000 lph* |
| | **g. Cost of delivered water** | *Rs. 30 per cubic meter* | |
| | **h. Electricity needs** | ***Domestic:*** *No* | ***Community:*** *1.5 kWh- 30 KWh required for operating the pump.* |

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| | **i. Does filter water meet the BIS no: 10500 of 2012?** | *Yes* |
| 2 | **Contaminants Removed** | *Arsenic, Iron and Bacteriological contamination* |
| 3 | **Reject Management** | *Spent media meet Toxicity Characteristics Leaching Protocol (TLCP)* |
| 4 | **Uniqueness of the Product** | |
| | ❖ *Low cost of the filter media appropriate for the socio-economic conditions of our country.*<br>❖ *No power requirement (Domestic filter)*<br>❖ *Removal of Arsenic, Iron and bacteriological contamination in a single unit.*<br>❖ *Arsenic concentration in filtrate is less than 10 ppb (WHO limit)*<br>❖ *Life of the filter is 5 years*<br>❖ *No regeneration needed during its lifetime*<br>❖ *Spent material meets TCLP protocol and can be safely disposed*<br>❖ *Easy maintenance*<br>❖ *Cost of treated water is 3 paise / litre* | |
| 5 | **Achievements** | |
| | ❖ *Development of highly efficient modified laterite adsorbent (24 mg/g of arsenic V).*<br>❖ *Design and installation of electricity free arsenic filter for domestic (120 L/day) and community (500 L/day) scale integrated with alum dosing to remove iron and bacterio-static carbon to remove coliform.*<br>❖ *Removal capacity of arsenic is 32.5 mg/g which is the maximum among other materials.*<br>❖ *Filtrate contain arsenic within <10 ppb which is within WHO limit. (1 mg/ lt, WHO limit is 10 mg/lt))*<br>❖ *Evaluation of 10 domestic filter and 1 community filter revealed successful performance.* | |
| 6 | **Publication/ Patents generated** | |
| | *Book: S. De and A. Maiti, "Arsenic removal from contaminated groundwater using laterite based adsorption technique", by TERI Press, ISBN: 9788179933831, 2011, India*<br>*Patents:*<br>❖ *"Design of a laterite based arsenic filter for domestic and community scale", filed for Indian Patent (430/KOL/2013).*<br>❖ *"Development of high capacity and cost effective arsenic adsorbent using modified laterite", filed for Indian patent (614/KOL/2009).* | |
| 7 | **Relevance of the output of project** | |
| | ❖ *Approved by Arsenic Task Force, Govt. of West Bengal.*<br>❖ *Approved by PHED, West Bengal. Life of the unit is 5 years (~ 1800 days).*<br>❖ *UNICEF, West Bengal has approved the field testing of the technology*<br>❖ *Evaluated by FOSET water testing Laboratory, Kolkata, Departmental Research Facility, Chemical Engineering, IIT Kharagpur, Kharagpur*<br>❖ *Technology transferred to* Vas Bros Enterprises Private Limited, 199/A, Mandelia Nagar, Bariatu Road, Ranchi, Jharkhand 834 009 | |
| *8* | ***Locations of Field Trials*** | |
| | ❖ *25 Household filter units installed in West Bengal*<br>➢ *Lalgola, Murshidabad (August, 2012)* | |

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| | ➢ *Behrampur, Murshidabad, (August, 2012)*<br>➢ *Baruipur, South 24 Pargana, (September, 2012)*<br>➢ *Rajarhat, North 24 Parganas, (October, 2012)*<br>➢ *Bamangachi, Barasat, North 24 Parganas, ( in March, 2011 rest in October, 2012)*<br>➢ *Habra, North 24 Parganas (September, 2012)*<br>❖ *3 Community filter units installed so far in West Bengal*<br>➢ *Kashinathpur free primary school, Rajarhat, North 24 Parganas,*<br>➢ *Ambika Girls High School, Rajarhat, North 24 Parganas*<br>➢ *Chouduar Primary School, Ratua II Block, Malda* |
| *9* | **Contact Details of Principal Investigator** |
| | Prof. Sirshendu De,<br>Membrane Separation Lab,<br>Department of Chemical Engineering ,<br>Indian Institute of Technology, Kharagpur-721302<br>*Phone:* +91 - 3222 – 283926<br>Email: sde@che.iitkgp.ernet.in |
| *10* |  <br><br>*Community scale filter of 500 litre /day installed in a primary school in Kashinathpur in Rajarhat, near Kolkata*<br>   <br>*Domestic filters with their proud owners* |

## 4.2 Arsenic Filter by Indian Institute of Technology- Bombay

IIT Bombay has developed a community scale hand pump attached arsenic removal filter using indigenous Zero-Valent Iron (ZVI) technology. The method is based on corrosion of ZVI and generation of hydrous ferric oxides (adsorbent for arsenic) and subsequent filtration. The process is so designed that oxidation of As (III) to As (V) is achieved and also the As (V) formed is adsorbed on hydrous ferric oxide (HFO). These models function in the absence of electricity and with direct inlet from hand pump. The salient features of this filter are as below:

- The filter uses locally available materials and is fabricated by local plumbers and masons.
- The process achieves oxidation of As (III) to As (V) & subsequent arsenic removal by hydrous ferric oxide, which is formed from oxidation of leached $Fe^{2+}$, without the addition of any chemicals.
- The unit is cost-effective, robust and does not require extensive monitoring.
- Designed operational Fe/As ratio is 15 which has taken into consideration phosphate presence and also factor of safety of 3. This is much lower than all other reported systems.
- This low Fe/As ratio makes the unit simple to operate and require less maintenance.
- Twenty times less sludge is generated, as compared to current technologies, due to efficient utilization of iron as seen from low Fe/As ratio.
- The unit has a simple design which enables easier replication locally, wherever required.
- The filter provides drinking water to meet the daily needs of around 200-300 families.
- The filter is able to achieve arsenic level of <10µg/l from initial arsenic concentrations up to 750 µg/l (tested at field) and more than 2000 µg/l (tested in lab) at a flow rate of 600-1000 l/h.
- The cost for producing 1 cubic metre of water (average monthly requirement for a family of 5 persons) varies from Rs. 0.10 to Rs. 1.00 (inclusive of maintenance of hand pump, iron replenishment and filter washing labour cost).

| SN | Features | Description |
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| 1. | **Product Definitions** | |
| | **a. Product Name** | IITB Arsenic Filter |
| | **b. Type of Product** | *Community Filter* |
| | **c. Cost of Unit** | *Rs. 60000-75000* |
| | **d. Technology Used** | Dual Stage- gravel filtration with iron nails and jali for supplementing iron for arsenic removal. Removal process based on dissolution of iron to Fe2+ from ZVI (iron nails + Jali) and co-oxidation of Fe2+ and As3+ which is co-precipitated with Fe3+. The gravel media has very long life but reactive media (Iron nail + iron Jali) need to be supplemented in a year time. |
| | **e. Flow rate** | *600-1000 lph* |
| | **f. Cost of delivered water** | *Rs. 3.3 per cubic meter* |

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| | **g. Electricity needs** | *No* |
| | **h. Does filter water meet BIS no: 10500 of 2012?** | *Yes* |
| 2. | **Contaminants Removed** | *Arsenic* |
| 3. | **Reject Management** | *A brick masonry tank is especially designed for sludge storage.* |
| 4. | **Uniqueness of the Product** | |
| | Indigenous technology using iron nails and locally available aggregates, plastic pipes and bucket material, typically consisting of two tanks in series which are attached to a hand pump. | |
| 5. | **Achievements** | |
| | ❖ Development of a simple process that uses indigenous Zero Valent Iron and a specially designed unit (which ensures good oxygen transfer, separation of Hydrous Ferric Oxide (HFO) flocs and uses locally available low cost granular media) for Arsenic removal from drinking water.<br>❖ 2 units operating at a flow rate of 600 lph in villages of West Bengal from February 2008.<br>❖ 53 more such units installed in various parts of Uttar Pradesh, Bihar, West Bengal and Assam. | |
| 6. | **Publication / Patents** | |
| | Patent filed. | |
| 7. | **Relevance of the output of project** | |
| | Indigenous technology using iron nails and locally available aggregates, plastic pipes and bucket material typically consists of two tanks in series which are attached to a hand pump | |
| *8.* | ***Location of Field Trials*** | |
| | ❖ 53 units in various parts of Uttar Pradesh, Bihar, West Bengal and Assam.<br>❖ 2 of these units have been installed in villages in Nadia District of West Bengal<br>❖ 3 units installed in 2010 at Polasi (N 24 Parganas), Kalyani Mor and Sonakhali (Nadia district) | |
| *9.* | **Contact Details of Principal Investigator** | |
| | Dr Sanjeev Chaudhari,<br>Professor, Center for Environment Science and Engineering,<br>Indian Institute of Technology Bombay, Powai, Mumbai- 400 076<br>Phone: 022-25767855, 25768855, 25767851, 25767852<br>Email: sanjeev@iitb.ac.in | |
| *10* |   <br>*IIT B Arsenic removal units in West Bengal* | |

## 4.3 *AMRIT- Arsenic and Metal Removal by Indian Technology- Indian Institute of Technology- Madras*

AMRIT is an affordable solution for providing clean drinking water in arsenic affected areas. It is a gravity-fed water purification unit in which arsenic and iron containing water is passed through a composite filter unit to obtain water, conforming to international standards. The solution has been implemented at various levels - homes, small communities and large scale water supply programs. The process of synthesis is exceptionally simple – it is prepared in a manner as nature prepares sea-shells, materials are made at room temperature in water, yet the materials are stable in water. These aspects make the innovation scientifically unique, green and sustainable

Compact water purification unit: Additionally, the design is enabled by the use of advanced materials which makes the water purification units miniaturized. Such a compact system is not possible without the use of these novel materials for water purification.

Unique product design adapted to rural India: The intent behind the design of the product was to make a simple product which works effectively in the field, yet it should convey Indian-ness of the product. The design is inspired from a coconut which is known to contain one of the finest forms of drinking water made by Mother Nature.

Materials used in AMRIT are reported to be world's best engineered nanostructured materials for the removal of health-related contaminants in water (M. Udhaya Sankar et al. PNAS, 110(2013) 8459-8464; The new water technologies that could save the planet, The Guardian, UK, 22nd July 2013).

| *S N* | *Features* | *Description* | |
|---|---|---|---|
| 1 | **Product Definition** | | |
| | **a. Product Name** | *AMRIT- Arsenic and Metal Removal by Indian Technology* | |
| | **b. Type of Product** | *Domestic and Community Filter* | |
| | **c. Cost of Unit** | ***Domestic:*** *Rs. 1500* | ***Community:*** *Rs. 99,000* |
| | **d. Technology Used** | *Multiple stage 1st stage: Surface Filtration, 2nd stage: Colloidal Iron adsorption, 3rd stage: Arsenic adsorption, 4th stage: Metal-based disinfection* | |
| | **e. Flow rate** | ***Domestic:*** 3 lph | ***Community:*** 100-1000 LPH (gravity-flow), up to 20,000 LPH (motor-powered flow) |
| | **f. Cost of delivered water** | ***Domestic:*** *50-70 cubic meter* | ***Community:*** *50 per cubic meter* |
| | **g. Electricity needs** | Domestic: No | Community: No |

| | | |
|---|---|---|
| | **h. Does filter water meet the BIS no: 10500 of 2012?** | *Yes* |
| 2 | **Contaminants Removed** | *Arsenic , Iron and turbidity* |
| 3 | **Reject Management** | |
| | Media can be easily disposed in the environment as it is prepared with facile and eco-friendly materials. Media can also be used for brick making as it is composed of iron oxides. | |
| 4 | **Uniqueness of the Product** | |
| | ❖ A water purifier for arsenic and iron free drinking water, based on iron oxyhydroxide, a nanostructured material to remove arsenic<br>❖ Functions without electricity or piped water supply<br>❖ Developed by Department of Chemistry,IIT Madras<br>❖ The design is inspired from a coconut thus making the innovation scientifically unique, green and sustainable.<br>❖ All materials and technologies are patented. Over 35 Indian/PCT patents have been filed. | |
| 5 | **Achievements** | |
| | ❖ AMRIT is an affordable, compact, gravity-fed water purification unit which provide clean drinking water conforming to international standards.<br>➢ It has been implemented at various levels - homes, small communities and large scale water supply programs. 200 household units demonstrated in Yadgiri District of Karnataka, Murshidabad district in West Bengal and in Bihar.<br>➢ 160 units of community filter demonstrated in villages spread across the districts of Murshidabad and Nadia, (West Bengal)<br>❖ Arsenic Task Force of West Bengal government certified and approved the purifier | |
| 6 | **Publication / Patents** | |
| | *Indian Patents:*<br>1. A method of preparing purified water from water containing pesticides (chlorpyrifos and malatheon) and purified water prepared by the said method, A. Sreeekumaran Nair and T. Pradeep, Indian patent 200767<br>2. Polyurethane foam coated with silver nanoparticles, Prashant Jain and T. Pradeep, Indian patent, 219111<br>3. A method to produce supported noble metal nanoparticles in commercial quantities for drinking water purification, A. Sreekumaran Nair and T. Pradeep, 1879/CHE/2007<br>4. A method for removing inorganic mercury from drinking water, K.P.Lisha, Anshup and T. Pradeep, Application No. 169/CHE/2009.<br>5. Removal of fluoride, alkalinity, heavy metals and suspended solids simultaneously adsorbent synthesis, adsorbent composition and a device for affordable drinking water, Shihabudheen M. Maliyekkal, Anshup and T. Pradeep, Application No. 2082/CHE/2009. | |

6. Organic polymer-inorganic fine particle antimicrobial composites and uses thereof, A. Sreekumaran Nair and T. Pradeep, 2052/CHE/2009.

7. Organic-templated-boehmite-nanoarchitecture: An adsorbent composition to remove arsenic and fluoride from drinking water, T. Pradeep, Shihabudheen M. Maliyekkal, Anshup, M. Udhaya Sankar and Amrita Chaudhary, 1529/CHE/2010.

8. A single component method and device for pathogens and heavy metals free water, Amrita Chaudhary, T. Saraladevi, Shihabudheen M. Maliyekkal, M. Udhaya Sankar, Anshup and T. Pradeep, 2433/CHE/2010.

9. Reduced graphene oxide-based composites for the purification of water, T. Pradeep, M. M. Shihabudheen and T.S. Sreeprasad, 2563/CHE/2010.

10. Gravity-fed axial flow filter block for domestic water purifiers and the method of making the same, T. Pradeep, M. Udhaya Sankar, Anshup and Amrita Chaudhary, 2892/CHE/2010.

11. A sustained silver release composition for water purification, T. Pradeep, Anshup, Amrita Chaudhary, M. Udhaya Sankar, and S.Gayathri, 947/CHE/2011.

12. One container gravity fed storage water purifier, T. Pradeep, Amrita Chaudhary, M. Udhaya Sankar and Anshup, 1522/CHE/2011.

13. Removal of pesticides from water using graphenic materials, T. Pradeep, Shihabudeen Maliyekkal and T. S. Sreeprasad, 3587/CHE/2011.

14. Multilayer organic-templated-boehmite-nano architecture for fluoride removal, T. Pradeep, A. Leelavathi, Amrita Chaudhary, M. Udhaya Sankar and Anshup, 4062/CHE/2011.

15. Reactivation of silver metal particle-based antimicrobial compositions, T. Pradeep, Amrita Chaudhary, M. Udhaya Sankar, Sahaja Aigal, Anshup, 4300/CHE/2011.

16. Visible detection of quantity of water flow using quantum clusters, T. Pradeep, Leelavathi A, M. Udhaya Sankar, Amrita Chaudhary, Anshup, T. Udayabhaskararao, 1521/CHE/2012.

17. Methods for selective visual detection of TNT, T. Pradeep, Ammu Mathew and P. R. Sajanlal, 3150/CHE/2012.

18. A method for the preparation of immobilized graphene-based composite from asphalt and its application in water purification, T. Pradeep, Soujit Sengupta, T. S. Sreeprasad and S. M. Maliyekkal, 3863/CHE/2012

19. A granulation composition for powder ingredients, T. Pradeep, A. Anil Kumar, Anshup, M. Udhaya Sankar, Amrita Chaudhary, 486/CHE/2013.

20. Water filled organic templated metal oxide/ hydroxide/oxyhydroxide particle network for water purification and a device thereof, T. Pradeep, M. Udhaya Sankar, Anshup, Amrita Chaudhary, A. Anil Kumar, 525/CHE/2013.

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| | 21. A composition for enhanced biocidal property and a water purification device based on same, T. Pradeep, M. U. Sankar, A. Chaudhary, S. Aigal, Anshup, Indian patent application 2867/CHE/2013.<br><br>*PCT/US/Europe patents*<br><br>1. A method for the preparation of adsorption compositions including gold and silver nanoparticles, US7968493<br><br>2. A method for decontaminating water containing pesticides, EP 1715947<br><br>3. Organic polymer-inorganic fine particle antimicrobial composites and uses thereof, PCT/IB2010/002016<br><br>4. Organic templated nanometal oxyhydroxide, PCT/IB2011/001551<br><br>5. Axial flow filter block for water purification, PCT/IB2011/002790<br><br>6. A sustained silver release composition for water purification, PCT/IB2012/001079<br><br>7. Single container gravity-fed storage water purifier, PCT/IB2012/001237<br><br>8. Multilayer organic-templated-boehmite-nano architecture for water purification, PCT/IB2012/002885<br><br>9. Graphene based antimicrobial composites, Application number 13443408.<br><br>10. Water purification unit, PCT/US2012/032880<br><br>11. Detection of quantity of water flow using quantum clusters, PCT/IB2013/001244<br><br>*Design patents*<br>1. Anti-gravity water filter cartridge, Design patent application 260460 dated February 19, 2014<br><br>2. AMRIT drinking water tank, Design patent application 257312 dated October 09, 2013<br><br>3. Water purifier, Design patent number 254443 dated June 11, 2013 |
| 7 | **Relevance of the output of project** |
| | ❖ *All materials and technologies are patented. Over 35 Indian/PCT patents filed.*<br>❖ *Arsenic Task Force of West Bengal government has certified and approved the purifier.*<br>❖ *The purifier is evaluated by Thematic Unit of Excellence on Clean Water (A DST run facility at IIT Madras)* |
| *8* | ***Location of Field Trials*** |
| | ❖ *200 household units demonstrated in Yadgiri District of Karnataka, Murshidabad district of West Bengal and in Bihar*<br>❖ *160 units of community filter demonstrated in villages spread across the districts of Murshidabad and Nadia, (West Bengal)* |

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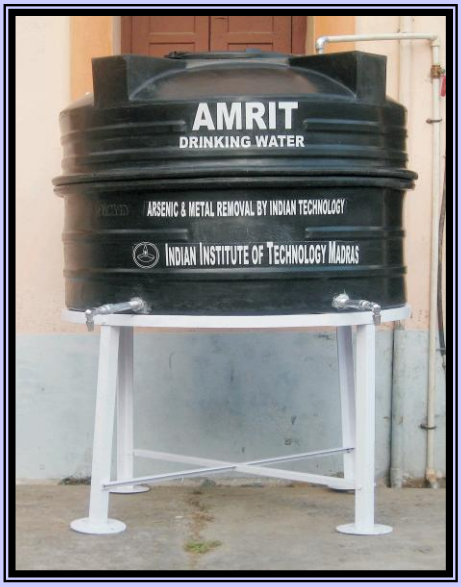
| *9* | **Contact Details of Principal Investigator** |
| | Prof T. Pradeep,<br>Professor,<br>DST Unit of Nanoscience and Thematic Unit of Excellence on Clean Water,<br>Department of Chemistry<br>Indian Institute of Technology Madras, Chennai 600 036<br>Phone: +91-44-2257 4208<br>Email: pradeep@iitm.ac.in |
| *10* |  <br>AMRIT, Domestic Arsenic Filter<br>  <br><br>AMRIT community water purification unit |

## 4.4 Arsiron Nilogon Arsenic Filter by Tezpur University

This filter removes arsenic and iron by Oxidation-Coagulation at Optimized pH (OCOP). Here the arsenic and the iron present in groundwater are oxidised from As(III) (arsenite) and Fe(II) (ferrous) states to As(V) (arsenate) and Fe(III) (ferric), respectively by using an oxidizing agent, *viz*., potassium permanganate ($KMnO_4$) and then coagulated using a coagulant, *viz*. ferric chloride ($FeCl_3$) at an optimized pH range controlled by adding sodium bicarbonate (baking soda or cooking soda, $NaHCO_3$) before oxidation and coagulation. Aeration of the water reduces the required quantity of $KMnO_4$. The water is then filtered using any filter, preferably a sand-gravel filter fitted with a filtration assisting device. The process removes arsenic as well as iron from contaminated water. Arsenic can be removed to/below 5 ppb (μg/L) from up to 500 ppb of initial concentration. Similarly, iron can be removed to/below 0.1 ppm (mg/L) from up to 20 ppm of initial concentration. The method is very simple and a plumber or a school teacher can be easily trained to operate or use it. The potassium permanganate and ferric chloride solutions can be obtained from chemical stores through science teachers of schools or colleges.

There is no limitation in the technology with respect to capacity of system and quantity of water to be treated. The system can be custom designed to meet the requirements of a household or a community.

***The Household Arsiron Nilogon System (HAN)*** requires a bucket (strong enough to withstand the weight of the sand and the gravels) of 25-30 lt capacity as a sand-gravel filter. A filtration assisting device made of ½ inch PVC pipe and joints and GI fittings.

| S N | Features | Description | |
|---|---|---|---|
| 1 | **Product Definition**<br>**a. Product Name** | Arsiron Nilogon | |
| | **b. Type of Product** | *Domestic and Community Filter* | |
| | **c. Cost of Unit** | ***Domestic:*** *Rs. 600* | ***Community:*** *Rs. 9000 for 200 lph batch capacity and Rs. 13000 for 500 lph batch capacity* |
| | **d. Technology Used** | *Multiple stage:* ***1st stage:*** *Oxidation-coagulation-adsorption- sedimentation* ***2nd stage:*** *Slow Sand Filtration* | |
| | **e. Flow rate** | ❖ It works in batch mode (typical flow rate of household filter is 200 lph and community filter is ~ 500 lph).<br>❖ There is no restriction in size of the reactor or system.<br>❖ It can be demonstrated with 10 litre or more of water in a bucket for household use<br>❖ It can be scaled up with hundreds of litres for small community or school<br>❖ It also can be further upscaled for large public water | |

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|---|---|---|---|
| | | supply scheme involving lakhs of litres. | |
| | **f. Cost of delivered water** | ***Domestic:*** *Rs. 31.67 per meter cube* | ***Community:*** *Rs. 48 per meter cube (200 lt) and Rs. 37 per meter cube (500 lt)* |
| | **g. Electricity needs** | ***Domestic:*** *No* | ***Community:*** *No* |
| | **h. Does filter water meet BIS no: 10500 of 2012?** | *Yes* | |
| 2 | **Contaminants Removed** | *Arsenic and Iron* | |
| 3 | **Reject Management** | | |
| | ❖ The small solid sludge, which very well passes the TCLP test of the US-EPA, can be disposed safely.<br>❖ There is no reject water. | | |
| 4 | **Uniqueness of the Product** | | |
| | ❖ It is based on oxidation-coagulation at optimized pH.<br>❖ The arsenic concentration is reduced to permissible range of 5 ppb from up to 500 ppb.<br>❖ Iron concentration is reduced to less than 0.1 ppm.<br>❖ No other toxic residue is left. The increments in the concentrations of Na, K and Cl are insignificant.<br>❖ The cost of treated water is approximately *Rs.* 1 per 100 litre. | | |
| 5 | **Achievements** | | |
| | ❖ The filter removes Arsenic and Iron simultaneously from ground water.<br>❖ Development of a method based on oxidation-coagulation at optimum pH.<br>❖ The filter can work with 10 litre or more of water in a bucket for household use<br>❖ Technique uses three common chemicals for coagulation and adsorption of Arsenic.<br>❖ Cost effective, user-friendly and works without electricity.<br>❖ Very small amount of sludge collected and sludge shows very low leaching (<10 ppb)<br>❖ Several thousand people benefitted by community filter and household filters | | |
| 6 | **Publication / Patents** | | |
| | Patent Filed: Arsenic removal from groundwater by oxidation-coagulation at controlled pH for domestic and community applications Application No.: "704/KOL/ 2010" dated 30/06/2010 11:58:50" | | |
| 7 | **Relevance of the output of project** | | |
| | ❖ Indian Patent filed. The cost of treated water is approximately *Rs.* 1 per 100 litre.<br>❖ The arsenic contamination is reduced to negligible concentration of 5 ppb from up to 500 ppb.<br>❖ Iron concentration is reduced to less than 0.1 ppm. Technology works at optimised pH.<br>❖ Evaluated by North Eastern Regional Institute of Land and Water Management (NERIWALM), Tezpur | | |
| *8* | ***Location of Field Trials*** | | |
| | ❖ 25 Household filter units installed so far in West Bengal<br>❖ Totoya Gaon, Majuli, District Jorhat, Assam Installed in 2013<br>❖ Sariyohtoli, Lakhanabondha, District Nagaon, Assam Installed in 2014<br>❖ Dangdhara, Titabor, District Jorhat, Assam Installed in 2014 | | |

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| | ❖ Tantigaon, Titabor, District Jorhat, Assam Installed in 2010<br>❖ Community Filter: 1 (in PHED supply scheme) at Jyoti Nagar in Golaghat town of Golaghat district in Assam and in 6 Schools |
| *9* | **Contact Details of Principal Investigator** |
| | Dr. Robin Kumar Dutta,<br>Professor, Department of Chemical Sciences, Tezpur University,<br>Napaam, Tezpur - 784028, Assam.<br>Phone: +91 3712 267007/8/9 EXTN 5055 (O)<br>Email: robind@tezu.ernet.in |
| *10* |   <br>*Community models for Arsiron Nilogon arrangements*<br>  <br>*Household Arsiron Nilogon system with sand-gravel filter alone (HAN)* |

## *4.5 DRDO Arsenic Removal Filter by Defence Research and Development Organisation*

A novel domestic arsenic removal filter has been developed by Defence Research and Development Organization (DRDO). The filter is user friendly, cost effective, easy to maintain and does not require any power supply for its operation. It utilises locally available processed waste of Steel Industry for co-precipitation of arsenic with iron. The filter was successfully evaluated in the field in terms of its efficiency for the removal of arsenic, iron and bacteria from ground water. The technology was transferred to the NGO `Save The Environment' to demonstrate and implement the technology in the arsenic affected villages. The technology was also transferred to M/s Shiva Engineering Pvt. Ltd Kolkata and M/s S B Equipments, New Delhi

The arsenic removal filter, works on the simple principle of co-precipitation of arsenic with iron and adsorption of this precipitate on iron oxyhydroxides, followed by further retention of this precipitate in treated sand. Arsenic removal filter has been designed and fabricated in clay, plastic and in stainless steel. The filter was demonstrated and evaluated in the arsenic affected rural areas of Bihar, West Bengal and UP.

| S N | Features | Description |
|---|---|---|
| 1 | **Product Definition**<br>**a. Product Name** | DRDO Arsenic Removal Filter |
| | **b. Type of Product** | *Domestic Filter* |
| | **c. Cost of Unit** | *Rs.2000* |
| | **d. Technology Used** | *Multiple stage: 1st stage (co-precipitation & adsorption) 2nd stage (Filtration)* |
| | **e. Flow rate** | 15 lph |
| | **f. Cost of delivered water** | *Rs. 0.015 per cubic meter* |
| | **g. Electricity needs** | *No* |
| | **h. Does filter water meet BIS no: 10500 of 2012?** | *Yes* |
| 2 | **Contaminants Removed** | *Arsenic* |
| 3 | **Reject Management** | *Media after use is converted in to non leachable cement bricks* |
| 4 | **Uniqueness of the Product** | |
| | Household type, simple, cost effective and highly suitable for rural population | |
| 5 | **Achievements and milestones of the Project** | |
| | ❖ Technology sourced from Naval Materials Research Laboratory (NMRL) Ambernath (DRDO).<br>❖ Design of Cost effective, non power requiring, environment friendly, easy to maintain & domestic Arsenic removal filter<br>❖ Utilisation of locally available processed waste of Steel Industry for co-precipitation of | |

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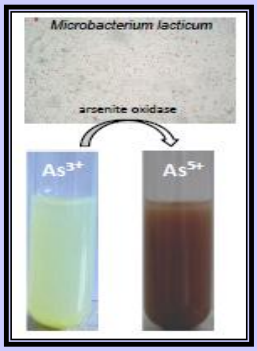
| | arsenic with iron.<br>❖ Demonstration in North 24 Paraganas (West Bengal), Balia (UP) and Bhagalpur (Bihar). |
| 6 | **Publication /Patents** |
| | ❖ Indian Patent No. 221078<br>❖ UK Patent No. GB2443149<br>❖ Vietnam Patent No. 1-2008-00790<br>❖ USA Application No. 0308,484 |
| 7 | **Relevance of the output of project** |
| | ❖ Household type, simple, cost effective and highly suitable for Rural population. Indian, UK and Vietnam Patent. Filed USA Patent.<br>❖ The product has been evaluated by Industrial Toxicology Research Centre (ITRC), Lucknow (NABL accredited), National Environment Engineering Research Institute (NEERI), Nagpur under UNICEF sponsored project and Presidency University, Kolkata. |
| *8* | **Location of Field Trials** |
| | Total ~2400 families and ~12000 people in these villages have benefitted by this technology from March 2007 to December 2011<br>❖ Village Lalmath situated in Nadia district of West Bengal, benefitting 1250 vilagers<br>❖ Tiwaritola, Bajraha, Baburani, Sripalpur, Murlichhapra, Dubyechhapra, Ramagarh, Reoti of Balia (Uttar Pradesh) and<br>❖ Gosaidaspur, Mathurapur, Rasidpur, Bhagalpur (Bihar). |
| *9* | **Contact Details of Principal Investigator** |
| | Dr. Pahari Basu,<br>SAVE the Enviroment, Kailash Ghosh Road,Kolkata- 700 008<br>Email: save1990env@yahoo.co.in<br><br>Dr. Kshipra Mishra,<br>Additional Director/Scientist `F' and Head,<br>Department of Biochemical Sciences (DBCS), Defense Institute of Physiology and Allied Sciences (DIPAS), Lucknow Road, Timarpur, Delhi-110054<br>Phone: 91-11-23883303<br>Email: kshipra misra <kmisra99@yahoo.com> |
| *10* |  <br>*Three Types (Stainless Steel, Clay and Plastic) DRDO Water Filters in display*<br>  <br>*Reject Management by converting the waste into non leachable cement bricks.* |

## *4.6 ARI Groundwater Arsenic Treatment Plant by Agarkar Research Institute*

Agharkar Research Institute (ARI) has developed a unique, cost effective 'integrated microbial oxidation alumina oxidation-adsorption process' for the removal of arsenic from groundwater rendering it completely safe. It is based on the process that *Microbacterium Lacticum* can oxidize arsenite ($As^{3+}$) in groundwater rapidly to arsenate ($As^{5+}$). Bacterium has a natural isolate possessing high arsenic tolerance; Non-pathogenic to humans, cattle etc. The filter also *removes any odor, color or sloughed off cells from water. The treatment capacity of the filter is 1000 lt/ day which can be easily scalable upto 10000 lt/day. The filter can be operated and maintained by unskilled workers. The system is developed after rigorous third party evaluation and is demonstrated at 5 locations in the state of Chhattisgarh. The salient features of this filter are given below:*

- Efficient under widely varying conditions of:
  - ✓ pH (6.0 – 8.0)
  - ✓ Temperature (10 – 45 °C)
  - ✓ Groundwater arsenic concentration (0.025 mg/L to > 5.0 mg/L
  - ✓ Presence of iron, sulfate, chlorides, phosphates etc.
- Cost-effective (treatment cost 10 paise/L)
- Treated water characteristics
  - ✓ Arsenic concentration <0.010 mg/L
  - ✓ Coliform count – nil
  - ✓ pH – same as inlet
  - ✓ No odour

| *S N* | *Features* | *Description* |
|---|---|---|
| 1 | **Product Definition**<br>**a. Product Name** | ARI groundwater arsenic treatment plant |
| | **b. Type of Product** | *Community Filter* |
| | **c. Cost of Unit** | *Rs.74,000* |
| | **d. Technology Used** | *Multiple stage (assembled single integrated unit)* ***1st stage:*** *Microbial oxidation (Bio-oxidation of As3+ to As5+ using a bacterium Microbacterium Lacticum immobilized on brick pieces)* ***2nd stage:*** *Adsorption of arsenate (As5+) on alumina.* ***3rd stage:*** *Filtration using charcoal to remove odour, color, microbial cells.* ***4th stage:*** *Ultra Violet Radiation for disinfection* |
| | **e. Flow rate** | *600-700 mL/min i.e. ~40 lph* |
| | **f. Cost of delivered water** | *Rs. 10 per cubic meter* |
| | **g. Electricity needs** | *Yes, 90 units per month* |
| | **h. Does filter water meet BIS no: 10500 of 2012?** | *Yes* |
| 2 | **Contaminants Removed** | *Arsenic* |

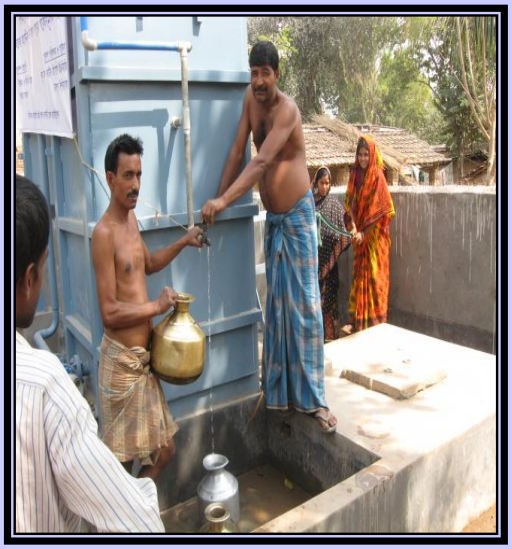
| | |
|---|---|
| 3 | **Reject Management** |
| | The wash water from the columns is collected in a separate container and 3% Ferric chloride is added to it to form an arsenic iron complex (indicated by the formation of a red precipitate). The resulting sludge is then disposed off in the concrete pit after drying. |
| 4 | **Uniqueness of the Product** |
| | The technology uses a unique process, viz. "Integrated Microbial oxidation-Alumina Adsorption Process" for arsenic removal. Oxidation of arsenic ($As^{3+}$) is a pre-requirement for its removal by adsorption. Conventional methods rely on chemical oxidation of trivalent arsenic to its penta-valent form. Owing to microbial oxidation, ARI process is eco-friendly. |
| 5 | **Achievements** |
| | ❖ Use of Microbacterium Lacticum to oxidize arsenite ($As^{3+}$) rapidly to arsenate ($As^{5+}$).<br>❖ Developed a unique 'integrated microbial oxidation alumina adsorption process for the removal of arsenic from groundwater rendering it completely safe.<br>❖ Feasibility on applicability of flat sheet liquid membrane based separation process for removal of Arsenic from groundwater. |
| 6 | **Publication/ Patents** |
| | Not patented |
| 7 | **Relevance of the output of project** |
| | ❖ 5 systems have been installed in Koudikasa and Muraithitola villages in Chhattisgarh<br>❖ Evaluated by Bhilai Institute of Technology, Bhilai and Pt.Ravishankar Shukla University Raipur<br>❖ Oxidation of $As^{3+}$ is a pre-requirement for its removal by adsorption. Conventional methods rely on chemical oxidation of trivalent arsenic to its pentavalent form. Owing to microbial oxidation, ARI process is eco-friendly. Expected life of the unit is 5 years. |
| *8* | ***Location of Field Trials*** |
| | *5 systems installed for community use in Koudikasa and Muraithitola villages in Chhattisgarh* |
| *9* | **Contact Details of Principal Investigator** |
| | Dr. K.M. Paknikar, Director (Officiating)<br>Agharkar Research Institute, GG Agarkar Road Pune 411004,<br>*Phone:* +91-20-25654831<br>*Email: kpaknikar@gmail.com, director@aripune.org* |
| *10* |  <br>*ARI groundwater Arsenic removal unit*<br>  <br>*Microbacterium lacticum oxidizing arsenite (As3+) to arsenate (As5+).* |

## *4.7 Hand Pump Attached Arsenic Removal Unit by Jadavpur University*

The treatment process technology for removal of arsenic is based on the double principle of Oxidation & Co-precipitation and Adsorption. The oxidation of As (III) to As (V) is achieved by adding chlorine. Co-precipitation for removal of arsenate is achieved by adding alum (aluminum sulphate) in right proportion. During up-flow movement of water, arsenate or arsenite, if present are removed through adsorption process in activated alumina layer. The iron in water is also removed in the purification process. The salient informations of installed Arsenic Removal Unit are as below

- Present running capacity 4,800 L in 12 hours
- Per-capita supply (for drinking and cooking) 8 lt/d
- Maximum number of beneficiaries 600
- Arsenic concentration in raw water is 0.1667 mg/lt
- Arsenic concentration in treated water BDL to 0.008 mg/lt

| *SN* | *Features* | *Description* |
|---|---|---|
| 1 | **Product Definition**<br>**i. Product Name** | Arsenic Removal Unit |
| | **j. Type of Product** | Community Filter |
| | **k. Cost of Unit** | *Rs.* 1,75,000 |
| | **l. Technology Used** | Double stage technology- co-precipitation and adsorption method |
| | **m. Flow rate** | 800 lph to 1000 lph |
| | **n. Cost of delivered water** | *Rs.* 3.60 per cubic meter |
| | **o. Electricity needs** | No |
| | **p. Does filter water meet BIS no: 10500 of 2012?** | Yes |
| 2 | **Contaminants Removed** | *Arsenic and Iron* |
| 3 | **Reject Management** | |
| | *Arsenic-rich sludge is to be stored in underground reservoir. Arsenic sludge (1%) needs to be mixed with concrete for reject disposal. TCLP test shows leaching of arsenic within permissible limit.* | |
| 4 | **Uniqueness of the Product** | |
| | It is a two stage technology where co-precipitation and adsorption method have been used | |
| 5 | **Achievements** | |
| | ❖ *Field model (800-1000 lph) based on co-precipitation, adsorption and filtration mechanism developed for Arsenic removal.*<br>❖ *Hand-pump attached units demonstrated at 3 locations, each benefiting around 50 families.* | |

| | |
|---|---|
| | ❖ *Unit does not operate under pressure.*<br>❖ *Possibility of upscaling for higher capacity* |
| 6 | **Publication /Patents** |
| | Not patented |
| 7 | **Relevance of the output of project** |
| | ❖ *The upgraded method has been adopted by Public Health Engineering Department (PHED), West Bengal for installation of centralized Arsenic Removal Plant. Hand-pump attached units demonstrated in the fields.*<br>❖ *4 units demonstrated in Lalgola block Murshidabad*<br>❖ *Filter evaluated by School of Water Resources Engineering, Jadavpur University, Kolkata and some samples were verified by "Scientific Research Laboratory, Kolkata".* |
| *8* | ***Location of Field Trials*** |
| | *4 units demonstrated in Lalgola block of Murshidabad in West Bengal* |
| *9* | **Contact Details of Principal Investigator** |
| | Dr. Asis Mazumdar,<br>Faculty of Interdisciplinary Studies, Law & Management<br>Professor of Water Resources Engineering<br>Director, School of Water Resources Engineering,<br>Jadavpur University, Kolkata -700032, West Bengal<br>*Phone:* 91-33-2414 6979 (O)<br>*Email:* asismazumdar@yahoo.com |
| *10* |  <br>*Arsenic Removal Unit (ARU)*<br>  <br>*Villagers Collecting Drinking Water from ARU* |

## 5. ***Future Steps***

The findings of these R&D projects have resulted in several scientific publications in international journals of repute and patents on materials, techniques and processes. Besides the institutional mechanisms of individual institutions to take these projects to the next level, the Department is consciously making attempts to encourage individual researchers to further their research so that the research efforts could culminate into a socially useful output in the field. The outcomes of these research efforts are also shared at various inter-ministerial forums including core committee on Arsenic mitigation.

However, the limited experience of the department has revealed the need to have last mile connectivity to translate the research outputs to field. While these R&D projects have proven their potential at lab scale, demonstration of capabilities of these technologies to provide convergent solutions with possible up-scaling needs sustained efforts.

Evolving customized technological solutions for Arsenic removal from water suited to specific social context requires continued scientific and technological inputs. Recognising the immense value of the expertise developed and insight gained during the course of implementation of R&D activities for addressing water challenge related to Arsenic, the Department is continuing this activity as part of the plan programme and proposes to develop synergies with national and global R&D institutions state government, water resources ministry and other stakeholders. DST envisions:

- Strong collaboration with global and national R&D institutions in Arsenic related area including in-situ remediation of Arsenic from aquifer system.
- Capacity building of research professionals and water managers to handle Arsenic contamination related issues
- Evolve methodology for development of customised solutions suited to social context based on successful global interventions
- Develop synergies with line departments at Central/ State level for last mile connectivity of the research findings
- Evolve sustainable models with industry through viability gap funding, where ever necessary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