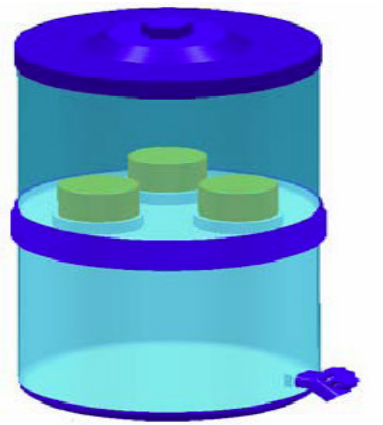
Water Technologies



September 7, 2010

CSIR
Council of Scientific and Industrial Research

नीरी
NEERI

Structure of Presentation

1. CSIR Interventions for water (2 minute)
2. Water treatment technologies (12 minutes)
   - Turbidity/micro-organisms
   - Fluoride
   - Iron
   - Arsenic
3. Membrane based technologies (3 minutes)
4. Source augmentation (2 minutes)
5. Conclusion (1 minute).

CSIR interventions in Water

- **Water resource mapping** : AMPRI, CIMFR, NEERI, NGRI
- **Water quality assessment**: CSMCRI, IITR, NEERI
- **Water augmentation**: AMPRI, CLRI, CSMCRI, IICT, NEERI, NGRI
- **Water purification**: CGCRI, CSMCRI, IMMT,NAL, NCL, NEERI, NEIST, NML

Technology Interventions by CSIR

Problem	Technology Solution
High Arsenic in water	Ceramic membrane based Arsenic removal Technology (CGCRI), Sand based technology (NML) Chemo-dearsenification (NEERI)
High Fluorides in water	RO based technology and waste treatment (CSMCRI), Electrolytic Defluoridation (NEERI), Chemo-defluridation (NEERI)
High iron contents in water	Ceramic membrane based Iron removal Technology (CGCRI), Hand Pump attachable removal unit (NEERI), NEERI-ZAR, Red clay based 'Terafil' unit (IMMT)
Breakish water (high TDS/salinity)	RO membrane based technology (CSMCRI)
High saline (brine) water in coastal areas	TFC RO membrane based technology (CSMCRI)
Presence of water borne pathogens such as, bacteria and viruses	Ultra-filtration membrane technology (NCL), Hollow Fibre membrane technology (CSMCRI)
	NEERI-ZAR, Red clay based 'Terafil' unit (IMMT)

Water Treatment Technologies
Turbidity & Micro-organisms

"NEERI-Zar"- Portable Instant Water Filter

- Chemical oxidation, sand filtration and disinfection
- No power requirement and gravity operated
- Capacity 18-20 L/h
- Produces water <3 NTU from raw water having turbidity 100-300 NTU
- Cost of the unit Rs. 2500 : Operating cost Rs 3 per 1000 L

Red Clay based Water Filtration Media – TERAFIL™ (IMMT)

- Prepared from the mixture of red clay (silt clay), river sand and wood saw dust
- Removal of about 99% of turbidity, 90-95% of micro-organisms and 90-95% of soluble iron
- Community Terafil water purification gravity flow stand-alone plants
- On-line Terafil pressure flow filtration unit (100 lit/hr) without using electricity

Water Treatment Technologies - Fluoride

Electrolytic Defluoridation

- Fluoride removal by polyhydroxy aluminum species produced by electrolysis using aluminium electrode
- Simultaneous reduction in bacterial contamination in treated drinking water
- Aluminium concentration in treated water below the permissible level
- Capital cost :
  - Construction of plant : Rs. 3 lakhs
  - Electrolytic system : Solar Rs. 3.0 lakhs/ Regular power : Rs. 1.0 lakh
- Operating cost Rs. 12 per 1000 liter of treated water

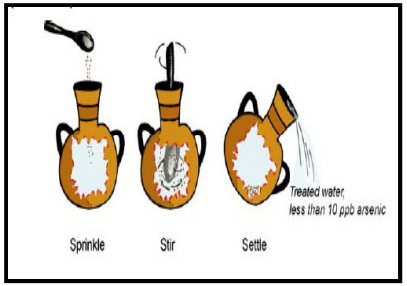
Chemo-Defluoridation

- Salts of calcium and phosphorous to reduce the fluoride
- Does not affect palatability of water unlike other chemical treatment process (Nalgonda Technology)
- Cost of the unit Rs. 2500
- Treatment cost : Rs. 0.2 per liter (Fluoride ~ 5 mg/L in raw water and <1 mg/L in treated water)

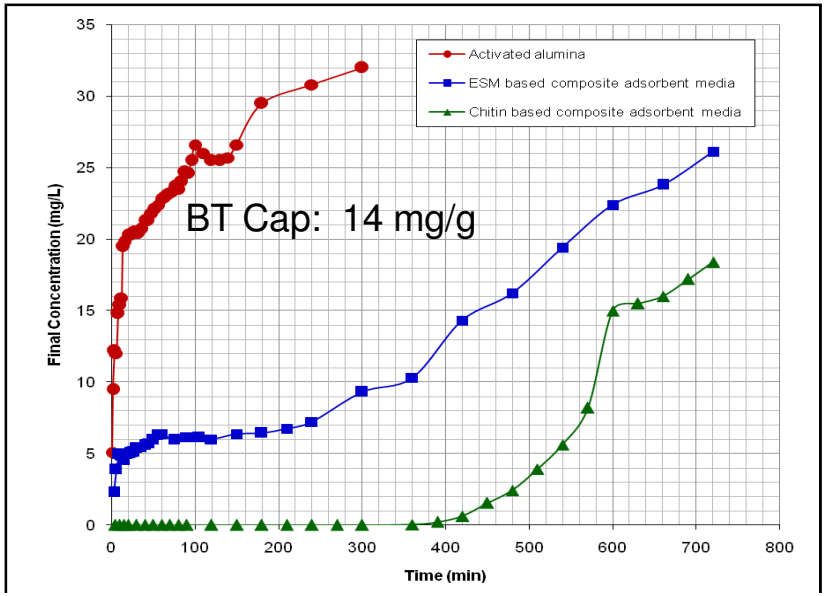
New Adsorbents for Defluoridation

- New composite type adsorbents with high adsorption capacity and selectivity
- Suitable for treatment of raw water with a wide range of initial fluoride levels and with high concentration of co-existing ions
- Estimated cost of adsorbent: Rs. 85 per kg
- Up-scaling of adsorbent synthesis completed up to 10 kg at SudChemie India Ltd.
- Laboratory scale batch and column trials completed with field water

Household techniques developed and user's perception study completed



Breakthrough Column Study



Field water: Initial F Conc.: 5.2 mg/L; Contact time 20 min

Adsorbent	Equilibrium capacity (mg/g)
NEERI-I	7.2
NEERI-II	4.7
Activated Alumina	1.1
Adsorbents tested for wastewater with higher 'F' content (50 ppm)	
NEERI	30.3
NEERI	37.0
Activated alumina	5.0

Water Treatment Technologies - Arsenic

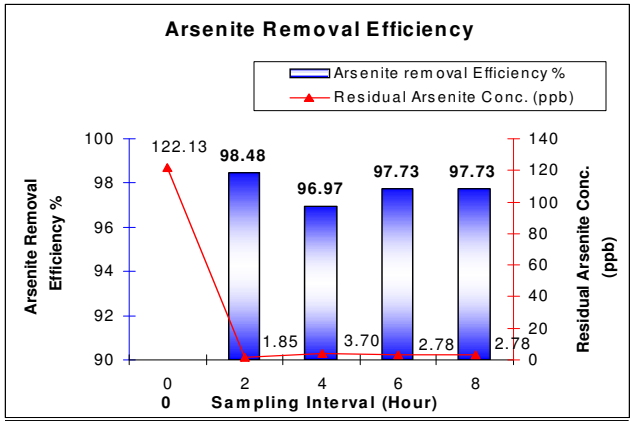
Ceramic Membrane Based Technology (CGCRI)

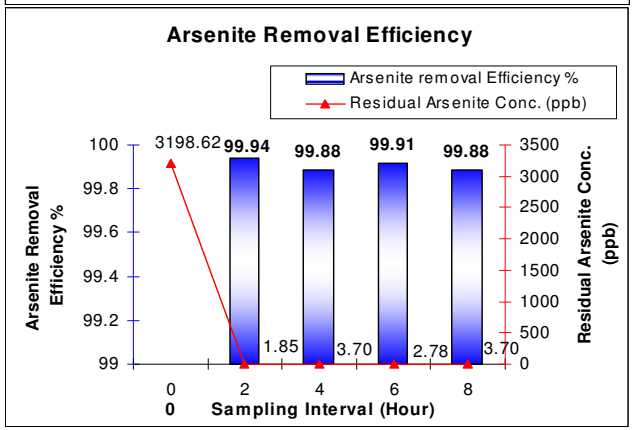
- Adsorption on nano-colloidal media and separation of suspended adsorbent using ceramic micro-filtration membrane modules
- Raw water : Arsenic : 2.7 mg/l and iron : 13 mg/l
- Simultaneous removal of arsenic, iron, turbidity
- Low pressure (< 2 Kg/cm^2) operation

Mineral based arsenic removal (NML)

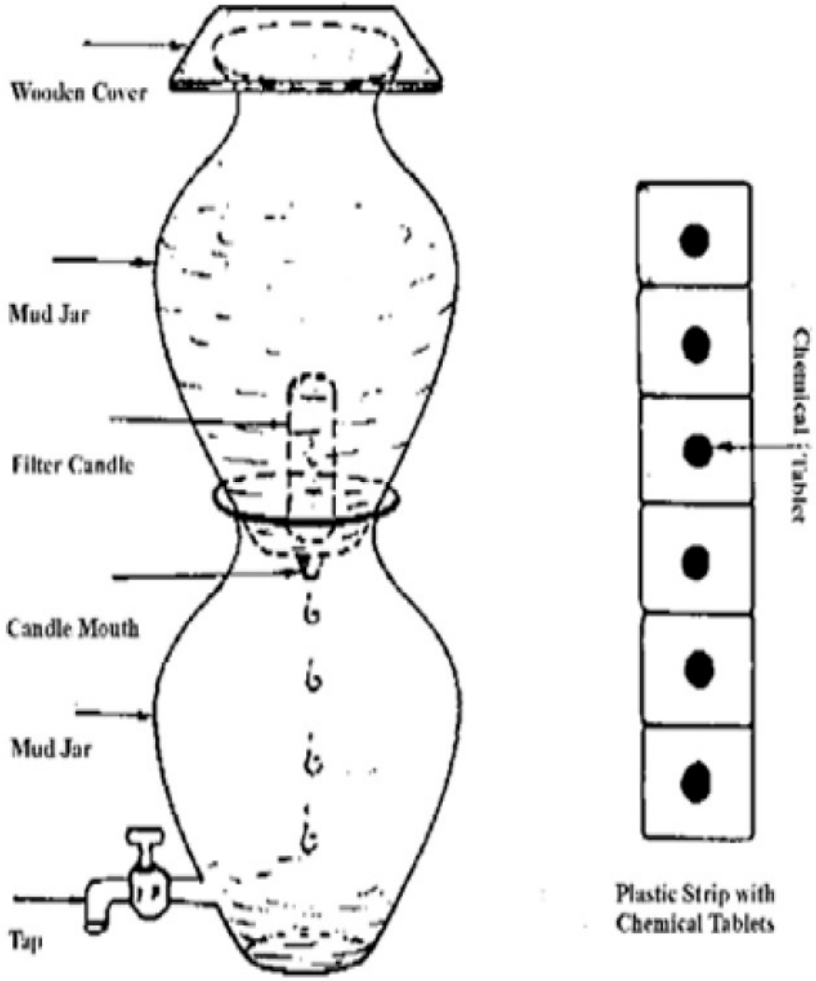
- Low cost mineral based adsorption media for removal of arsenic and iron
- Sludge can be easily contained however, requires a concerted methodology
- A three container set up with flexible material of construction (stainless steel to plastic). Clay set ups are also feasible

Chemo-dearsenification





Arsenic Removal by Filter and Black Tablet



- Filter made upof fly ash, clay and charcoal
- Black colored tablet contains Fe^{3+} salt, oxidizing agent and activated charcoal
- Useful for treatment 20 L arsenic contaminated water
- Usually 93-100% arsenic is removed

Arsenic removal by Filter-Tablet system, School of Environmental Sciences, Jadavpur University

Water Treatment Technologies - Iron

Hand Pump Attachable Iron Removal Plant

- Based on aeration, oxidation, precipitation, sedimentation and filtration
- 1 m^3/hour hydraulic loading
- Designed for 250 persons
- Construction cost ~ Rs. 50,000

- Potassium permanganate oxidises and precipitate iron in groundwater (0.5 mg per mg of iron)
- Cost of the unit Rs. 3000 : Operating cost Rs. 3 per 1000 L

Water Treatment Technologies

Membranes

RO Desalination at community level (600-1000 LPH) utilising renewable energy sources

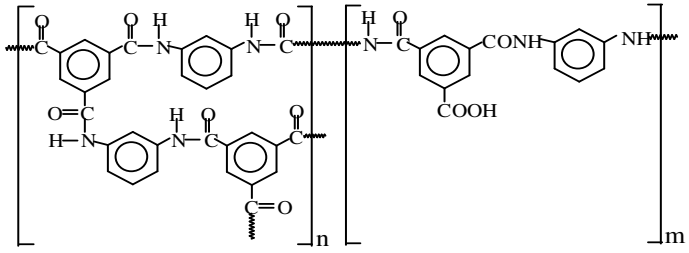
Solar powered brackish water RO plant (in partnership with Barefoot College)

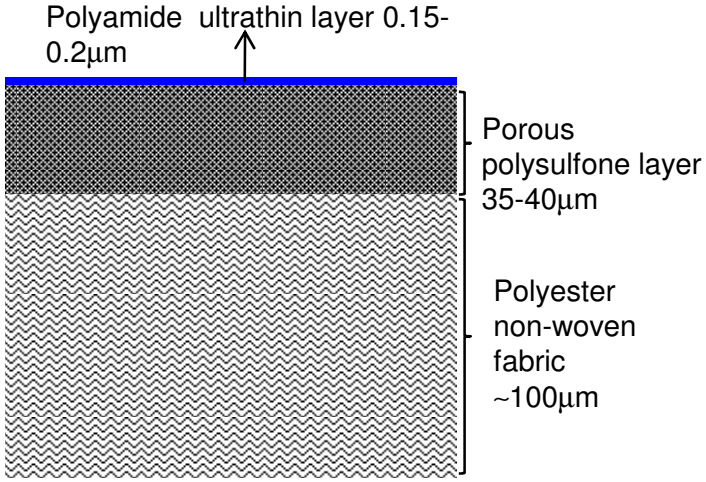
Patent Appln. No. :1550/DEL/2009

From modest beginnings supported by DDWS

5 more plants are being set up in Sambhar Lake area (Sinodiya, Jhag, Der ki Dhani, Solavta,Mordikala) in collaboration with FORRAD (funding courtesy Coca Cola India Foundation)

Thin Film Composite (TFC) RO Membrane Technology





Salient Features of the Technology

- Performance is proven for community scale desalination of brackish water (by single stage) and seawater (by two-stage) with production cost in the range of **2-12 paise per litre** depending on salinity and capacity.
- Membranes are also suitable for removal of **fluoride/arsenic/nitrate** and may be able to compete with other technologies on offer.; especially for large scale production.
- Flat sheet ultrafiltration membrane modules for **microorganisms removal** can also be fabricated from the intermediate PS membrane.

Membrane Assisted Iron Removal Technology

- **Max. Iron (Ferrous ion) in feed that can be treated: 20 ppm**
- **Consist of aeration, pH adjustment and ultra filtration**
- **Guaranteed product quality: Iron below 0.1 mg/l**
- **Product water also free from bacteriological contaminants**
- **50-5000 litres per day per unit Rs. 3000 and above**

BARC developed technology

Defluoridation of groundwater using Membrane Technology

Membrane based community level defluoridation plant, I.I.T Delhi Supported by DST, New Delhi

- Low energy (Nano-RO) Membrane technology
- Pilot scale plant with an output of 100 L/h
- Pressure requirements; 6 bar – 12 bar pressure
- Pretreatment of contaminated water by passing it through Sand filter, Activated carbon filter and Micron filter respectively to remove iron, organic matter, excess free chlorine and suspended matter to increase the life of membrane
- Installation cost is 1.5 – 7.0 lakhs in the range of 1.0 m^3 – 4.0 m^3 outputs of treated water

Membrane Assisted Fluoride Removal Technology

BARC developed technology

- Contaminated ground water is passed through activated alumina bed and the percolate is filtered through UF membrane.
- Max. Fluoride ion in feed that can be treated : 10ppm
- Nos. of Regeneration cycle of alumina bed: 10
- Product water free from aluminium (less than 0.1 ppm), biological and colloidal contaminants throughout the entire life cycle
- 50-5000 litres per day per unit Rs. 3000 and above

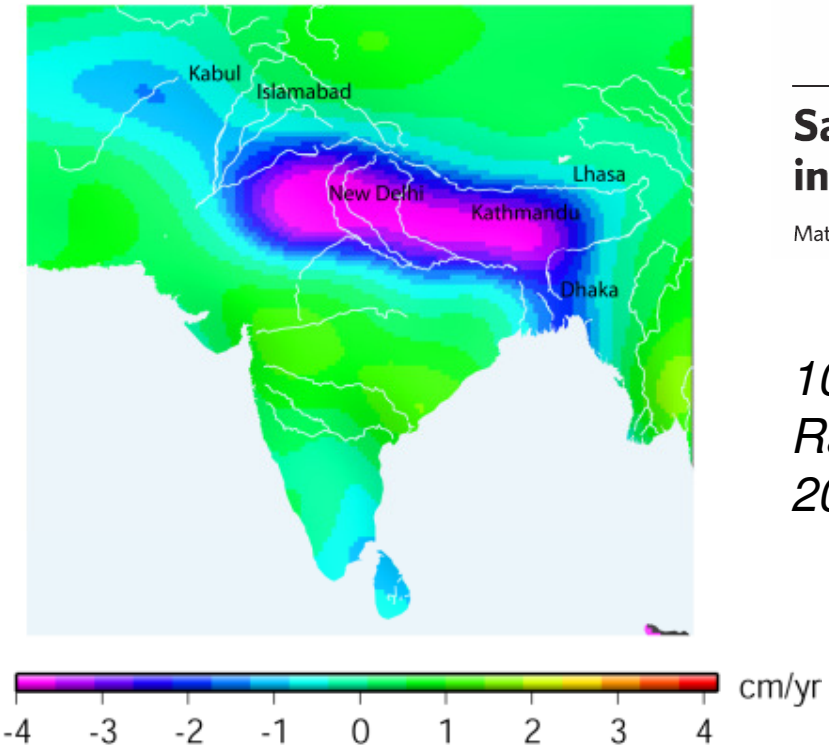
Source augmentation

Rainwater harvesting and artificial recharge (AMPRI, Bhopal)

Ghatiya Watershed in Ujjain district of Madhya Pradesh for creation of sustainable groundwater development for agriculture.

Strategies for cost-effective groundwater recharge during favorable monsoon periods and to make best use of flood water needs to be accorded high priority.

Looking at macro issues



Rate of water depletion in the northern India as equivalent water thickness in cm

An NGRI scientist, through a collaboration with international scientists, has also estimated (see map above) significant depletion of groundwater in northern India and the surrounding region (*Geophysical Research Letters*, 2009, published online). Such studies must dovetail into policies.

Vol 460|20 August 2009|doi:10.1038/nature08238 nature

LETTERS

Satellite-based estimates of groundwater depletion in India

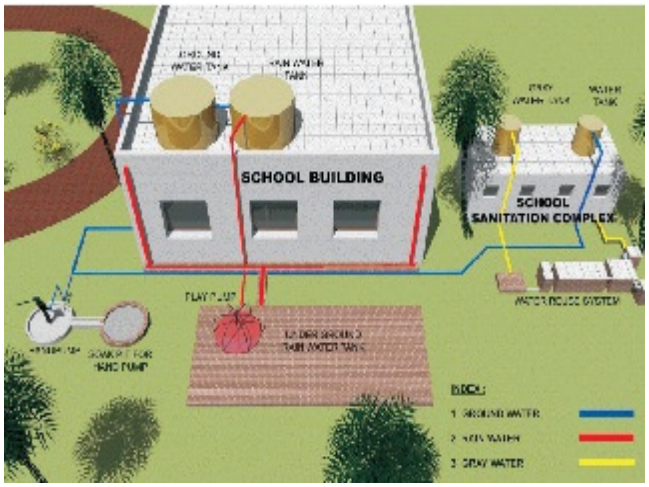
Matthew Rodell[1], Isabella Velicogna[2,3,4] & James S. Famiglietti[2]

109 km^3 of groundwater reported to be depleted in Rajasthan, Haryana and Punjab together during 2002-2008!

Other significant CSIR contributions in hydrogeology:

- Increasing the efficacy of tanks for agriculture in drought prone areas: Model studies in Maharashtra, Rajasthan and Andhra Pradesh.
- Delineation of Lithologic control in Arsenic contaminated areas in UP and Bihar using Electrical Resistivity Tomography and Time Domain EM methods.

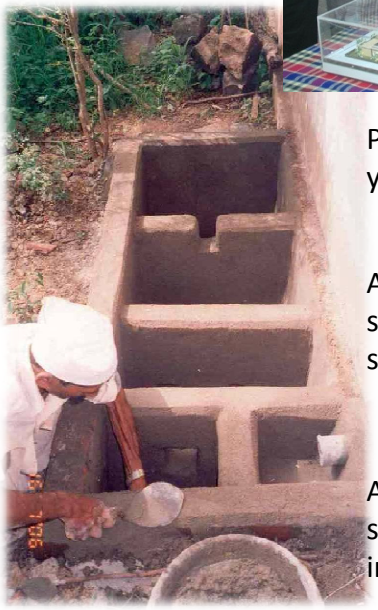
Greywater Treatment Technology



Saving of 20-30 liter of water per person per day

Cost varies from Rs 80,000 to Rs 150,000 to treat 5000 l/day to 20,000 l/day of greywater

Payback period estimated to be 2 years



Around 100 greywater treatment systems constructed in Ashram schools in Madhya Pradesh

Around 100 greywater treatment systems constructed in households in Madhya Pradesh

Raw Water → Primary Treatment
- Screening
- Sponge Filter
- Equalization tank

→ Secondary Treatment-I
- Gravel Filter
- Sand Filter

→ Secondary Treatment-II
- Broken brick
- Charcoal
- Chlorination

→ Treated Grey Water

Conclusion

- Cost-effective and sustainable water treatment technologies are developed by CSIR and other agencies
- These technologies are successfully demonstrated in the field
- Technologies can be disseminated in water quality affected rural habitations with the help from water supply agencies
- Technological logistics are important considerations

THANKS

Water Treatment Technologies

Nitrate Removal

Nitrate Removal by a Combined Catalytic & Ion-exchange Approach

Nitrate removal: Options

Biological Process:

- Slow and incomplete process
- Requires extensive maintenance
- Difficulties in control, sludge formation
- Dead biomass
- Post treatment essential

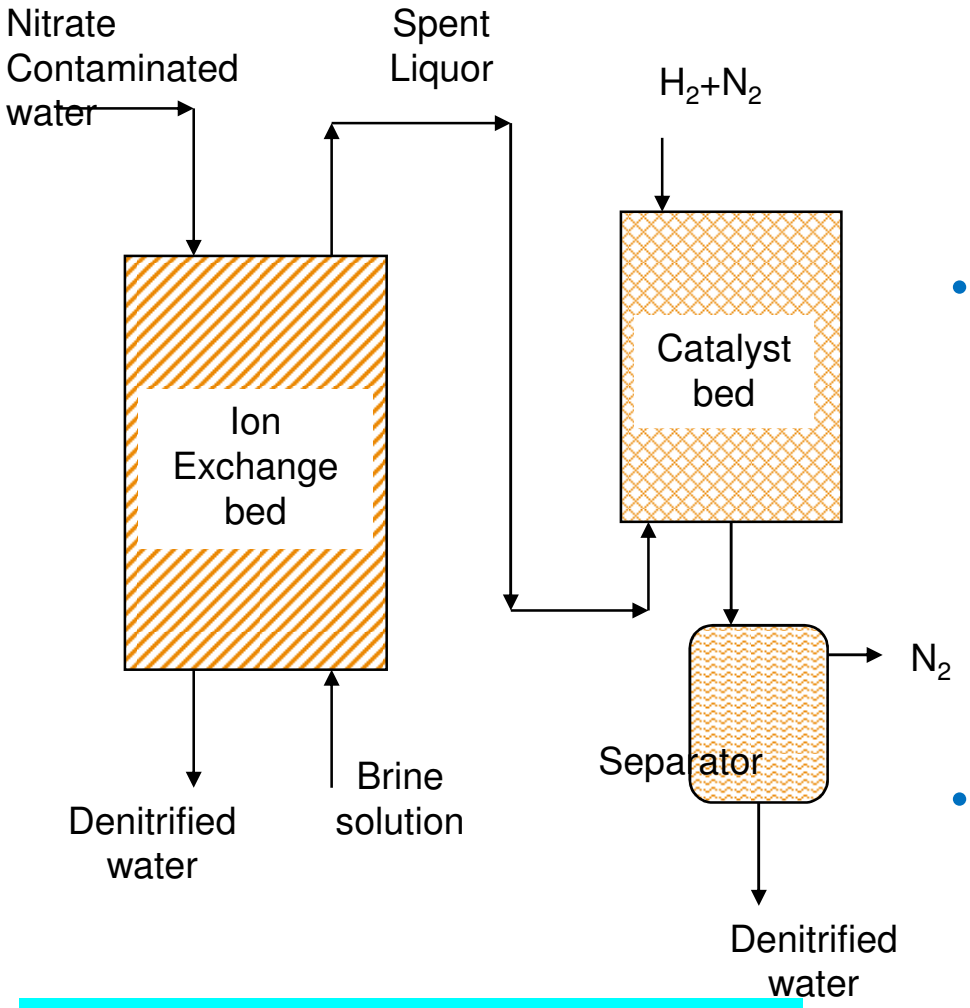
Catalytic route:

- Efficient
- Expensive
- Selective catalysts avoiding formation of ammonia
- Availability of reducing agent

Ion exchange:

- Efficient
- Disposal of the regenerant major problem

Potential Solution: Combination of Ion exchange and subsequent treatment of concentrated solution by catalytic denitrification process/Biological process



- Separating drinking water treatment for nitrate and catalytic reduction of nitrate from regeneration solution; no health issues
- Easy operation with less engery makes technology most potential.

- **Performance of catalysts for regenerate solution form ion-exchange column**
  - **Nitrate reduction 85%**
  - **Catalytic activity 0.5 mg/g/min (2x reported)**
  - **Selectivity to nitrogen nearly 100%**
  - **pH range 2.5 to 5**
- **Expected cost of treatment = 15 Paisa per liter**

Potential Technology for field demonstration

Adsorption and Co-precipitation Media for De-arsenification

- Arsenic removal using capsule containing 0.6 g of the adsorption/co-precipitation media
- Effective for removing up to 0.3 mg/l of Arsenic from 10 liter of water
- Arsenic in the treated water is below 0.005 mg/l.

Conclusion

- **Cost-effective and sustainable water treatment technologies are developed by CSIR**
- **These technologies are successfully implemented in the field**
- **Technologies can be disseminated in water quality affected rural habitations with the help from water supply agencies**
- **CSIR will provide essential training to water supply agencies for implementing technologies**

THANKS

from

Team CSIR

Membrane Techniques

- **Reverse Osmosis**
- **Nanofiltration**
- **Electrodialysis**
- **Donnan Dialysis**

Defluoridation of groundwater using Membrane Technology (Reverse Osmosis)

Membrane based community level defluoridation plant, I.I.T Delhi Supported by DST, New Delhi

- Low energy (Nano-RO) Membrane technology
- Pilot scale plant with an output of 100 L/h
- Pressure requirements; 6 bar – 12 bar pressure
- Pretreatment of contaminated water by passing it through Sand filter, Activated carbon filter and Micron filter respectively to remove iron, organic matter, excess free chlorine and suspended matter to increase the life of membrane
- Installation cost is 1.5 – 7.0 lakhs in the range of 1.0 m3 – 4.0 m3 outputs of treated water
- Designed by IIT Delhi supported by DST, New Delhi

Nanofiltration (NF)

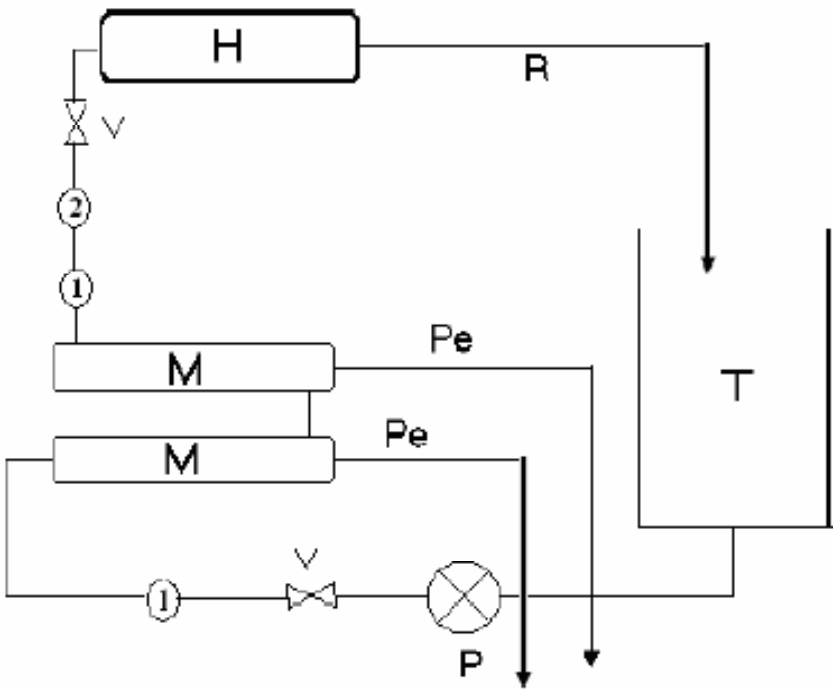


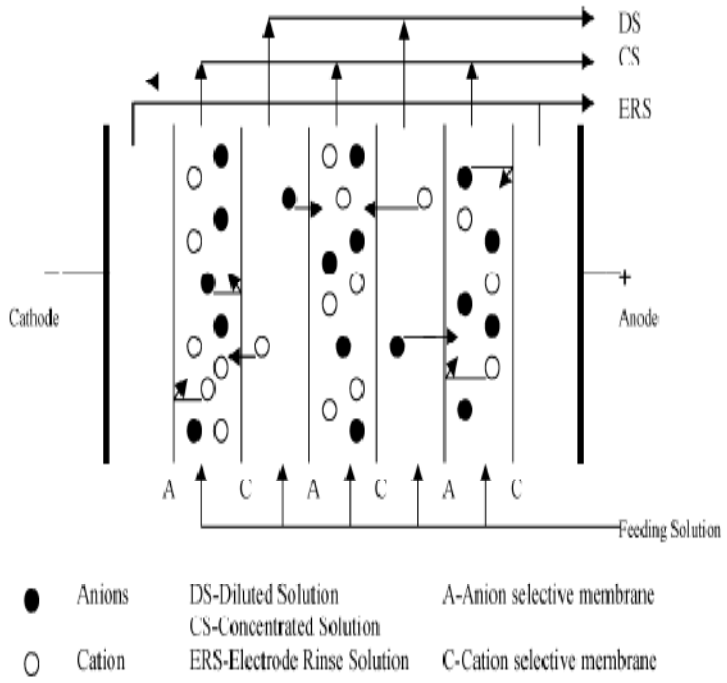
Diagram for Nanofiltration Pilot plant

- **NF is a process with the properties between reverse osmosis (RO) and ultrafiltration (UF)**
- **Widely applicable specially for drinking and wastewater treatment**
- **Requires less pressure and capital than RO**
- **Permeability of NF membranes is higher than those of RO**
- **NF membranes have high retention of charged particles, especially bivalent ions, making this technology suitable to remove hardness**
- **M. Tahaikt et al. Desalination 212 (2007) 46 – 53.**

Characteristics of the membranes used

Membrane	Cut off (Da)	Surface (m^2)	Material
NF90	90	7.6	Polyamide
NF400	400	7.6	Polyamide

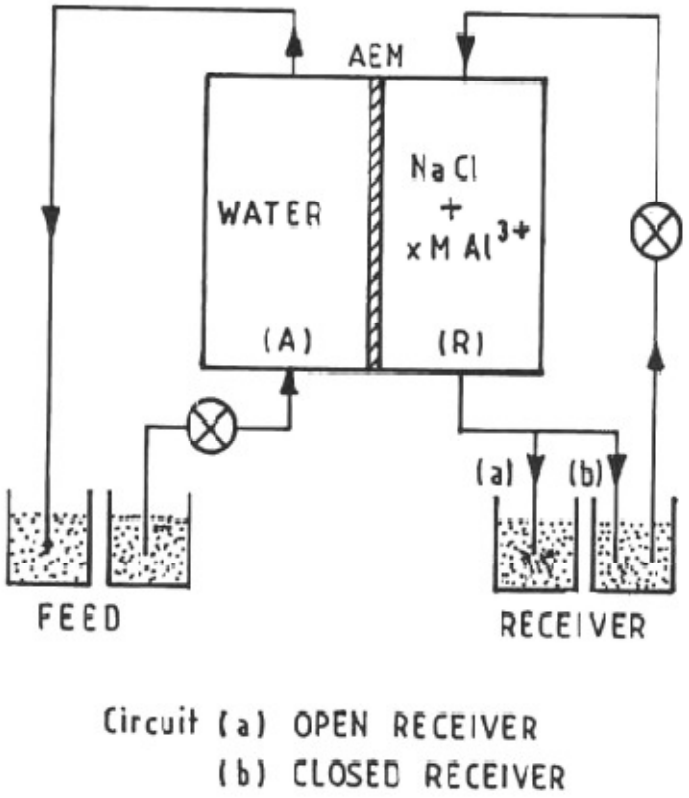
Electrodialysis (ED)



Schematic diagram of a typical Electrodialysis cell

- **Excellent technique for simulatneous defluoridation and desalination of brackish water at a reasonable cost of 2.5 – 5 KWh/m^3**
- **Stack containing 15 cell pairs of cation and anion- exchange membranes of 80 cm^2 effective cross - sectional area**
- **Interpolymeric films based on high – density polyethylene (HPDE)- linear low density polyethylene (LLDPE) – styrene divinylbenzene**
- **Reduced TDS and fluoride from 5000 ppm to 600 ppm and 15 ppm to 1.5 ppm respectively**
- **Expensive technique**
- **Skilled operators**
- **Adhikary et al. Desalination, 71 (1989) 301-312**

Donnan Dialysis (DD)



Circuit (a) OPEN RECEIVER
(b) CLOSED RECEIVER

Schematic flow diagram of Donnan Dialysis system

- **Membrane separation process that uses ion exchange membrane with concentration gradient as a driving force**
- **Operation requires addition of a so-called driving counter- ion to stripping solution**
- **Highly efficient in treating fluoride contaminated water**
- **Reduced efficiency in high – saline waters**
- **Expensive technique**

Water Technologies (Arsenic)

Coagulation/Filtration

- Efficiency of the process depends on the type of coagulant, dose etc.,
- Alum, Ferric sulphate (i.e. Iron addition) etc.
- Disposal of sludge may be a problem

Lime softening

- Operated at higher pH
- May not reduce arsenic within permissible limits
- Secondary treatment is required

Ion-exchange

- Effectively removes arsenic
- Interfering ions such as sulphate, selenium, fluoride and nitrate may compete

Reverse osmosis

- Effectively removes arsenic within permissible limits
- Discharge of reject water or brine may be a concern
- Requires high capital

Electrodialysis Reversal (EDR)

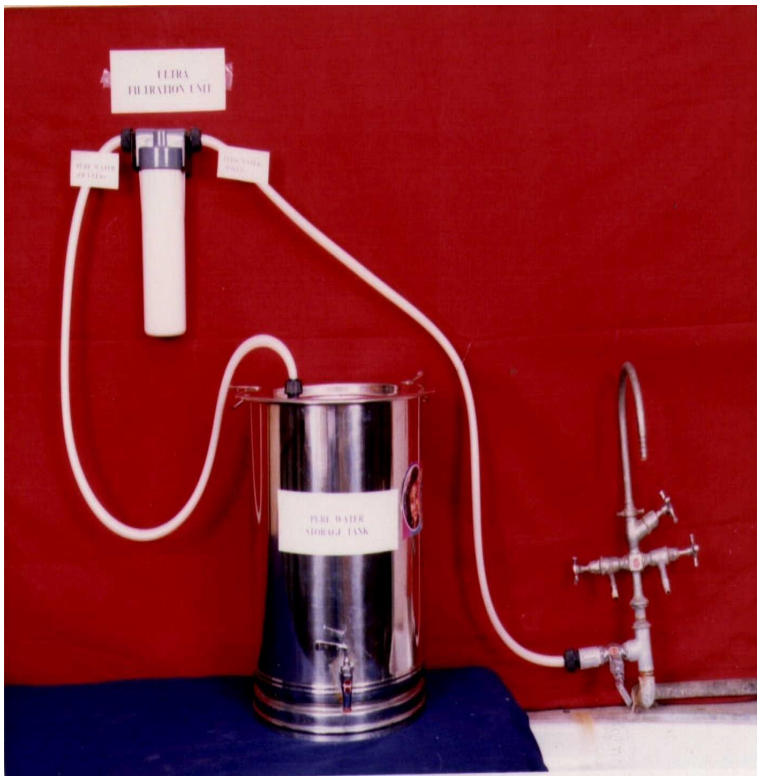
- Effectively removes arsenic within permissible limits
- High cost may be a concern

Nanofiltration (NF)

- Effectively removes arsenic within permissible limits
- Increased water recovery may increase the capital

Bhabha Atomic Research Centre

Domestic Water Purifier (BARC)



- Removal of suspended particles, colloidal particles and biological contaminants
- Flux restoration by backwash at 2 bar pressure
- Can replace sand filter and cartridge filter
- Single unit capacity varies from 1000-7000 LPD depending on dimensions. Rs. 6000 – 40,000 depending upon size

Back-washable Spiral Ultrafiltration (UF) technology for domestic and industrial water purification (BARC)

- Non electrical driven
- Product water free from biological and colloidal contaminants since passed through UF membrane.
- Max. Operable pressure : 2 kg/cm^2
- Filter life: More than 3 yrs (typical)
- 40-100 litres per day: Rs. 2000-5000

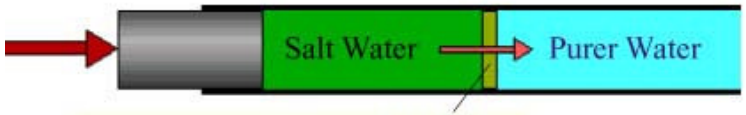
Membrane Assisted Fluoride Removal Technology (BARC)

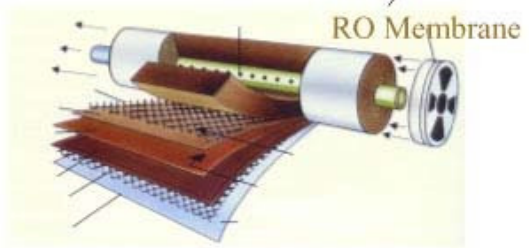
- Contaminated ground water is passed through activated alumina bed and the percolate is filtered through UF membrane.
- Max. Fluoride ion in feed that can be treated : 10ppm
- Nos. of Regeneration cycle of alumina bed: 10
- Product water free from aluminium (less than 0.1 ppm), biological and colloidal contaminants throughout the entire life cycle
- 50-5000 litres per day per unit Rs. 3000 and above

Membrane Assisted Iron Removal technology (BARC)

- Contaminated ground water is aerated and if required pH adjusted, followed by UF filtration.
- Max. Iron(Ferrous ion) in feed that can be treated: 20 ppm
- Different treatment scheme consisting aeration, pH adjustment and UF filtration depending upon iron level in feed water
- Guaranteed product quality: Iron below 0.1 ppm
- Product water also free from biological and colloidal contaminants since passed through UF membrane.
- 50-5000 litres per day per unit Rs. 3000 and above

Brackish water Reverse Osmosis (BWRO) technology





- Design of pretreatment – flexible-recirculation based RO design – post treatment.
- To conserve ground water source and minimal environmental burden.
- Conserves ground water sources.
- UF pretreatment system for reliability.
- Post treatment system for palatability and acceptability.
- Reject management with respect to harmful contaminants such as fluoride, arsenic etc.
- Site specific Design
- 10,000 - 50,000LPD Approx Rs 50 per LPD capacity

Central Glass & Ceramic Research Institute (CSIR)

Ion specific resin units for the removal of Arsenic / Iron from Drinking Water (CGCRI)

- Bulk removal of arsenic & iron by
- coagulation and precipitation from water
- Polishing of arsenic by ion specific resin
- Easy to install and operate Convenient to carry in the field
- Resin has good shelf life upon cycles of
- Regeneration
- 25 lit./hour to 100 Lit/hour Rs.3500-4000/ for 25 lit/hour capacity domestic unit

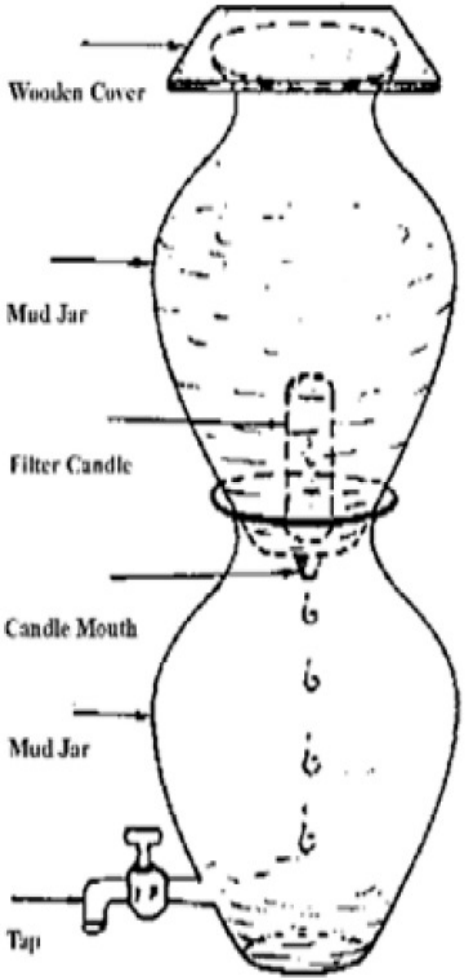
Ceramic Membrane based Plant for Arsenic and Iron Removal from Groundwater

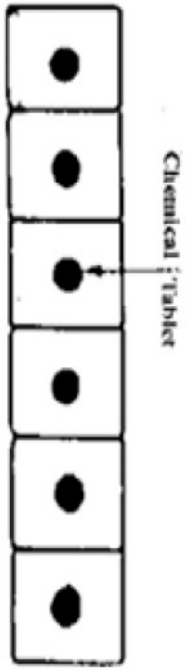
- Multielement modules with 19-channel ceramic elements
- Colloidal adsorbent media (required for arsenic removal).
- System designed using electrically operated pump fitted with membrane modules of different capacities.
- Process suitable for treatment of high iron and arsenic content in contaminated water with simultaneous removal of arsenic and iron
- Production of quality drinking water (comparable to packaged mineral water) as per WHO recommendation.
- 100 – 1000 LPH Rs. 1.5 – 5.0 Lakhs

Ceramic membrane based pretreatment system coupled with brackish water RO Plants for river Water Purification

- Turbidity removal using ceramic membrane modules
- TFC membrane modules for treatment of brackish water
- Lower space requirement due to smaller foot print of membrane modules
- 20,000-30,000 LPD Rs. 25-30 Lakh/unit

Arsenic Removal by Filter and Black Tablet





- Filter made upof fly ash, clay and charcoal
- Black colored tablet contains Fe^{3+} salt, oxidizing agent and activated charcoal
- Useful for treatment 20 L arsenic contaminated water
- Usually 93-100% arsenic is removed

Arsenic removal by Filter-Tablet system, School of Environmental Sciences, Jadavpur University

NEERI-ZAR in the flood affected area of Baitu Block of Barmer District, Rajasthan

Transportation and Installation of NEERI-ZAR in Sundarban District, West Bengal

Know-how is available free of cost for societal mission

Slow Sand Filtration

- Very efficient and reliable method of surface water treatment for rural water supplies
- A single step treatment for removal of marginal turbidity, organic matter, particulate matter and microorganisms
- Suitable pre-treatment needed when higher turbidities (> 30 NTU) for longer duration
- Can be constructed with locally available material by local craftsmen
- Operation and maintenance by local community
- No chemicals required (except disinfectant)
- No power-driven mechanical parts are present
- No wash water for cleaning of the filter
- Implemented in Maharashtra, Andhra Pradesh, Tamil Nadu and Uttarakhand