Reference Manual

Technologies available for removal of excess Arsenic, Fluoride, Salinity, Nitrate, Iron and Biological contamination in drinking water

Rajiv Gandhi National Drinking Water Mission
Department of Drinking Water Supply
Ministry of Rural Development
Government of India
New Delhi.

Technologies for removal of excess Arsenic in drinking water

ARSENIC REMOVAL TECHNOLOGIES

1. SORAS method

Solar Oxidation and Removal of Arsenic is a simple method that uses irradiation of water with sunlight in PET or other UV-A transparent bottles to reduce arsenic levels from drinking water. This SORAS method is based on photochemical oxidation of As(III) followed by precipitation or filtration of As(V) adsorbed on Fe(III) oxides. SORAS removes arsenic in a two step procedure. In the first step, As(III), which only weakly adsorbs to iron(hydr)oxides, is oxidized to the strongly adsorbing As(V). In the second step, Fe(III) (hydr)oxides formed from naturally present iron are allowed to settle to the bottom of the container with the adsorbed As(V) and the clear water is decanted. Instead of adding chemical oxidants such as chlorine or permanganate, reactive oxidants are produced photochemically with sunlight. This technology has been used in Bangladesh.

It is a simple arsenic removal process applied at household level with locally available resources. However, the arsenic removal efficiency is limited to approx. 50-70 % and hence raw water up to 100-150 mg/L can be treated with this method. The people like the taste and they say that food cooked with this treated water keeps its natural colour and freshness. People living in arsenic affected areas seem to be prepared to use the SORAS treatment method.

Reference: Martin Wegelin, Daniel Gechter, Stephan Hug, Abdullah Mahmud et al, Proceedings of the 26th WEDC conference, Dhaka, Bangladesh, 2000.

2. By Corrosion induced adsorption

This technology is executed by Instituto del Desierto (INDES) of the University of Antofagasta (Chile), together with the Dept. of Water Quality Control of the Technical University of Berlin (Germany).

It is a simple and cheap treatment system consisting of the three steps:-

1. Production of iron-hydroxide by corrosion of metal iron
2. Adsorption of arsenic on the freshly produced particles, and
3. Removal of the particles including their high arsenic load by sedimentation and sand filtration.

This technology has been pilot tested in the northern Chile.

Reference: K.Karschunke, V.L. Caceres and M.Jakel, Proceedings of the 26th WEDC conference, Dhaka, Bangladesh, 2000.

3. By coagulation process

This technology has been developed by NEERI, Nagpur, India. In a laboratory study, alum and poly aluminium chloride have been studied as coagulants in the removal of arsenic from ground water. The PAC used in the present study is Vikram Powder PAC AC/190. The findigs of the studies have shown that, the dose of poly aluminium chloride is almost half that of alum for obtaining the same level of arsenic removal.

Reference: K.Sri Bala Kameswari, A.G.Bhole, R.Paramasivam, P.L.Muthal and S.P.Pande, Journal of Indian Water Works Association, p.231, Oct-Dec 1999

4. Oxidation

Atmospheric oxygen, hypochloride, or permanganate is added to the water to oxidize arsenite to arsenate and thereby facilitate its removal.

Reference: Pierce, M.L. and Moore, C.B. (1982), Adsorption of Arsenite and Arsenate on amorphous iron hydroxide, Water Resources, 16, 1247-1253

5. Passive sedimentation

This method received considerable attention because of rural people's habit of drinking stored water from pitchers. Oxidation of water during collection and subsequent storage in houses may cause in reduction in arsenic concentration in stored water (Bashi Pani). Experiments conducted in Bangladesh showed zero to high reduction in arsenic content by passive sedimentation.

Reference: Ahmed M.F and Rahaman M. M.(2000), Water Supply and Sanitation - Low Income Urban Communities, International Training Network (ITN) Centre, BUET.

6. In-situ oxidation

In-situ oxidation of arsenic and iron in the aquifer has been tried under DPHE-Danida Arsenic Mitigation Pilot Project. The aerated tubewell water is stored in a tank and released back into the aquifers through the tubewell by opening a valve in a pipe connecting the water tank to the tubewell pipe under the pump head. The dissolved oxygen in water oxidizes arsenite to less mobile arsenate and also the ferrous iron in the aquifer to ferric iron, resulting a reduction in arsenic content in tubewell water. Experimental results show that arsenic in the tubewell water following in-situ oxidation is reduced to about half due to underground precipitation and adsorption on ferric iron.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

7. Co-precipitation and adsorption process

In the coagulation-flocculation process aluminium sulphate, or ferric chloride or ferric sulphate is added and dissolved in water under efficient stirring for one to few minutes. Aluminium or ferric hydroxide mocro-flocs are formed rapidly. The water is then gently stirred for few minutes for agglomeration of micro-flocs into larger easily settable flocs. During this flocculation process all kinds of microparticles and negatively charged ions are attached to the flocs by electrostatic attachment.

Reference: Ahmed M.F and Rahaman M. M.(2000), Water Supply and Sanitation - Low Income Urban Communities, International Training Network (ITN) Centre, BUET.

8. **Bucket treatment unit**

The Bucket Treatment Unit (BTU), developed by DPHE-Danida Project is based on the principles of coagulation, co-precipation and adsorption processes. It consists of two buckets, each 20 L capacity, placed one above the other. Chemicals are mixed manually with arsenic contaminated water in the upper red bucket by vigorous stirring with a wooden stick for 30-60 seconds and then flocculated by gentle stirring for about 90 second. The mixed water is then allowed to settle for 1-2 hrs. The water from the top red bucket is then allowed to flow into the lower green bucket via plastic pipe and a sand filter installed in the lower bucket. The flow is initiated by opening a valve fitted slightly above the bottom of the red bucket to avoid inflow of settled sludge in the upper bucket. The lower green bucket is practically a treated water container.

The units were reported to have very good performance in arsenic removal in both field and laboratory conditions. Extensive study of DPHE-Danida BTU under rapid assessment program showed mixed results. In many cases, the units under rural operating conditions fails to remove arsenic to the desired level of 0.05 mg/L in Bangladesh. Poor mixing and variable water quality particularly pH of groundwater in different locations of Bangladesh appeared to be the cause of poor performance in rapid assessment.

Bangladesh University of Engineering and Technology (BUET) modified this technology and obtained better results by suing 100 mg/L of ferric chloride and 1.4 mg/L of potassium permanganate in modified BTU units. The BTU is a promising technology for arsenic removal at household level at low cost. It could be built by locally available materials and is effective in removing arsenic if operated properly.

Reference: Sarkar, A, Thogersen, Choudhury, Rahaman, Akhter and Choudhury (2000),Bucket Treatment unit for arsenic removal, In Water, Sanitation andHygiene: Challenges of the Millennium, Pre-prints of the 26 WEDCConference, Dhaka, Bangladesh., 308-310.

9. **Stevens Institute Technology**

This technology consists of two buckets, one to mix chemicals (reported to be iron sulphate and calcium hypochloride) supplied in packets and the other to separate flocs by the processes of sedimentation and filtration. The second bucket has a second inner bucket with slits on the sides to help sedimentation and keeping the filter sand bed in place. The chemicals from visible large flocs on mixing by stirring with stick. The assessment report showed that the technology was effective in reducing arsenic to less than 0.05 mg/L in case of 80 to 95 % of the samples tested. The sand bed used for filtration is quickly clogged by flocs and requires washing atleast twice in a week.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

10. **Fill and Draw units**

It is a community type treatment designed and installed under DPHE-Danida Arsenic Mitigation Pilot project. It is 600 L capacity tank with slightly tapered bottom for collection and withdraw the settle sludge. The tank is filled with a manually operated mixer with flat-blade impellers. The tank is filled with arsenic contaminated water and required quantity of oxidant and coagulant are added to the water. The water is then mixed for 30 seconds by rotating the mixing device at the rate of 60 rpm and left overnight for sedimentation. The water takes some times to become completely still which helps flocculation. The floc formation is caused by the hydraulic gradient of the rotating water in the tank. The settled water is then drawn through a pipe fitted with at a level, few inches above the bottom of the tank and passed through a sand bed and finally collected through a tap for drinking purpose. The mixing and flocculation processes in this unit are better controlled to effect higher removal of arsenic. The experimental units installed by DPHE-Danida project are serving the clusters of families and educational institutions.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

11. Arsenic removal units attached to tubewell

The principles of arsenic removal by alum coagulation, sedimentation andfiltration have been employed in a compact unit for water treatment in the village level in West Bengal, India. The arsenic removal plant attached to hand tubewell has been found effective in removing 90 percent arsenic from tubewell water having initial arsenic concentration of 300µg/L. The treatment process involves addition of sodium hypochloride (Cl_2), and aluminum alum in diluted form, mixing, flocculation, sedimentation and up flow filtration in a compact unit.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

12. Chemical Packages

In Bangladesh, different types of chemical packages have been distributed in the form of tea bags, small packets and powder or tablet form for the removal of arsenic from drinking water. The principles involved in arsenic removal by these chemicals involve oxidation, sorption and co-precipitation. Application methodology and efficiency of any of these chemicals have not been fully optimized by long experimentation. Quality assurance and dose control in rural condition are extremely difficult. The residuals of added chemicals in water after treatment can do equal harm. The use of unknown chemicals and patented process without adequate information should be totally discouraged.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

13. SORPTIVE FILTRATION MEDIA

Several sorptive media have been reported to remove arsenic from water. These are activated alumina, activated carbon, iron and manganese coated sand,kaolinite clay, hydrated ferric oxide, activated bauxite, titanium oxide, siliciumoxide and many natural and synthetic media. The efficiency of all some sorptive media depend on the use of oxidizing agent as aids to sorption of arsenic. Saturation of media by different contaminants and components of water takes place at different times of operation depending on the specific sorption affinity of the medium to the given component. Saturation means that the efficiency in removing the desired impurities becomes zero.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

14. Activated Alumia

Activated alumia having good sorptive surface is an effective medium for arsenic removal. When water passes through a packed column of activated Lumina, the impurities including arsenic present in water are adsorbed on the surfaces of activated alumina grains. Eventually the column becomes saturated, first at its upstream zone and later the saturated zone moves downstream towards the bottom end and finally the column get totally saturated.

Regeneration of saturated alumina is carried out by exposing the medium to 4% caustic soda, NaOH, either in batch or by flow through the column resulting in a high arsenic contaminated caustic waste water. The residual caustic soda is then washed out and the medium is neutralized with a 2% solution of sulfuric acid rinse. During the process about 5-10% alumina is lost and the capacity of the regenerated medium is reduced by 30-40%. The activated alumina needs replacement after 3-4 regeneration. Like coagulation process, pre-chlorination improves the column capacity dramatically. Some of the activated alumina based sorptive media used in Bangladesh include:

- BUET Activated Allumina
- Alcan Enhanced Activated Alumina
- ARU of Project Earth Industries Inc.,USA
- Apyron Arsenic Treatment UnitThe

BUET and Alcan activated alumina have been extensively tested in field condition in different areas of Bangladesh under rapid assessment and found very effective in arsenic removal. The Arsenic Removal Units (ARUs) of Project Earth Industries Inc. (USA) used hybrid aluminas and composite metal oxides as adsorption media and were able to treat 200-500 Bed Volume(BV) of water containing 550 g/L of arsenic and 14 mg/L of The Apyron Technologies Inc. (ATI) also uses inorganic granular metal oxide based media that can selectively remove As(III) and As(V) from water. The Aqua-Bind™ arsenic media used by ATI consist of non-hazardous aluminium oxide and manganese oxide for cost-effective removal of arsenic. The proponents claimed that the units installed in India and Bangladesh consistently reduced arsenic to less than 10µg/L.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

15. Granular Ferric Hydroxide

M/S Pal Trockner(P) Ltd, India and Sidko Limited, Bangladesh installed several Granular Ferric Hydroxide based arsenic removal units in India and Bangladesh. The Granular Ferric Hydroxide (AdsorpAs®) is arsenic selective adsorbent developed by Technical University, Berlin, Germany. The unit requires iron removal as pre-treatment to avoid clogging of filter bed. The proponents of the unit claims to have very high arsenic removal capacity and produces non-toxic spent granular ferric hydroxide.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

16. Read-F Arsenic Removal Unit

Read-F is an adsorbent produced and promoted by Shin Nihon Salt Co. Ltd, Japan for arsenic removal in Bangladesh. Read-F displays high selectivity for arsenic ions under a broad range of conditions and effectively adsorbs both arsenite and arsenate without the need for pretreatment. The Read-F is Ethylene-vinyl alcohol copolymer(EVOH)-borne hydrous cerium oxide in which hydrous cerium oxide ($CeO_2 \cdot n H_2O$), is the adsorbent. The material contains no organic solvent or other volatile substance and is not classified as hazardous material. Laboratory test at BUET and field testing of the materials at 4 sites under the supervision of BAMWSP showed that the adsorbent is highly efficient in removing arsenic from groundwater.

Reference: Shin Nihon Salt Co. Ltd. (2000), Report on Performance of Read-F Arsenic Removal Unit (ARU), October.

17. Iron Coated Sand

BUET has constructed and tested iron coated sand based small scale unit for the removal of arsenic from groundwater. The iron content of the iron coated sand was found to be 25 mg/g of sand. Raw water having 300 µg/L of arsenic when filtered through iron coated sand becomes essentially arsenic-free. It was found that 350 bed volumes could be treated satisfying the Bangladesh drinking water standard of 50 ppb. The saturated medium is regenerated by passing 0.2N sodium hydroxide through the column or soaking the sand in 0.2N sodium hydroxide followed by washing with distilled water. No significant change in bed volume (BV) in arsenic removal was found after 5 regeneration cycles. It was interesting to note that iron coated sand is equally effective in removing both As(III) and As(V). Iron coated brick dust has also been developed in Bangladesh for arsenic removal from drinking water.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

18. Indigenous Filters

There are several filters available in Bangladesh that use indigenous material as arsenic adsorbent. Red soil rich in oxidized iron, clay minerals, iron ore, iron scrap or fillings and processed cellulose materials are known to have capacity for arsenic adsorption. Some of the filters manufactured using these materials include:

- Sono 3-Kolshi Filter
- Granet Home-made Filter
- Chari Filter
- Adarsha Filter
- Shafi Filter
- Bijoypur Clay/Processed Cellulose filter

The Sono 3-Kolshi filter uses zero valent iron fillings and coarse sand in the top Kolshi, wood coke and fine sand in the middle Kolshi while the bottom Kolshi is the collector of the filtered water (Khan et al., 2000). Earlier Nikolaidis and Lackovic (1998) showed that 97 % arsenic can be removed by adsorption on a mixture of zero valent iron fillings and sand and recommended that arsenic species could have been removed through formation of co-precipitates, mixed precipitates and by adsorption onto the ferric hydroxide solids. The Sono 3-Kolshi unit has been found to be very effective in removing arsenic but the media habour growth of microorganism.

The one-time use unit becomes quickly clogged, if groundwater contains excessive iron.

The Garnet home-made filter contains relatively inert materials like brickchips and sand as filtering media. No chemical is added to the system. Air oxidation and adsorption on iron-rich brick chips and flocs of naturally present iron in groundwater could be the reason for arsenic removal from groundwater. The unit produced inadequate quantity of water and did not show reliable results in different areas of Bangladesh and under different operating conditions. The Chari filter also uses brick chips and inert aggregates in different Charis as filter media. The effectiveness of this filter in arsenic removal is not known.

The Shafi and Adarsh filters use clay material as filter media in the form of candle. The Shafi filter was reported to have good arsenic removal capacity but suffered from clogging of filter media. The Adarsha filter participated in therapid assessment program but failed to meet the technical criterion of reducing arsenic to acceptable level. Bijoypurclay and treated cellulose were also found to adsorb arsenic from water (Khair, 2000).

Reference:

- *Khan, A.H., Rasul, S.B., Munir, A.K.M., Alauddin, M. Habibuddowlah, M. and Hussam,A (2000). On two simple arsenic removal methods for groundwater of Bangladesh, In In Bangladesh Environment-2000, M.F.Ahmed (Ed.), Bangladesh Poribesh Andolon, :151-173.*
- *Nikolaidis,N.P. and Lackovic, J. (1998), "Arsenic Remediation Technology-AsRT", presented at International Conference on Arsenic Pollution ofGround Water in Bangladesh: Causes, Effect and Remedies, Dhaka, 8-12 February*
- *Khair, A.(2000) Factors responsible for the presence of arsenic in groundwater:Bangladesh context, In Bangladesh Environment-2000, M.F.Ahmed (Ed.), Bangladesh Poribesh Andolon, :198-209.*

19. Cartridge Filters

Filter units with cartridges filled with soptive media or ion-exchange resins are readily available in the market. These unit remove arsenic like any other dissolved ions present in water. These units are not suitable for water having high impurities and iron in water. Presence of ions having higher affinity than arsenic can quickly saturate the media requiring regeneration or replacement. Two household filters were tested at BUET laboratories, These are:

- Chiyoda Arsenic Removal Unit, Japan
- Coolmart Water Purifier, Korea.

The Chiyoda Arsenic Removal Unit could treat 800 BV meeting the WHO guideline value of 10 μg/L and 1300 BV meeting the Bangladesh Standard of 50 μg/L when the feed water arsenic concentration was 300 μg/L. The Coolmart Water Purifier could treat only 20 L of water with a effluent arsenic content of 25μg/L (Ahmed et al., 2000). The initial and operation costs of these units are high and beyond the reach of the rural people.

Reference: Ahmed M.F and Rahaman M. M.(2000), Water Supply and Sanitation - Low Income Urban Communities, International Training Network (ITN) Centre, BUET.

20. ION EXCHANGE

The process is similar to that of activated alumina, just the medium is a synthetic resin of more well defined ion exchange capacity. The process is normally used for removal of specific undesirable cation or anion from water. As the resin becomes exhausted, it needs to be regenerated. The arsenic removal capacity is dependent on sulfate and nitrate contents of raw water as sulfate and nitrate are exchanged before arsenic. The ion exchange process is less dependent on pH of water. The efficiency of ion exchange process is radically improved by pre-oxidation of As(III) to As(V) but the excess of oxidant often needs to be removed before the ion exchange in order to avoid the damage of sensitive resins. Development of ion specific resin for exclusive removal of arsenic can make the process very attractive. Tetrahedron ion exchange resin filter tested under rapid assessment program in Bangladesh showed promising results in arsenic removal. The system needs pre-oxidation of arsenite by sodium hypochloride. The residual chlorine helps to minimize bacterial growth in the media. The saturated resin requires regeneration by recirculating NaCl solution. The liquid wastes rich in salt and arsenic produced during regeneration require special treatment. Some other ion exchange resins were demonstrated in Bangladesh but sufficient field test results are not available on the performance of those resins.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

21. MEMBRANE TECHNIQUES

Membrane techniques like reverse osmosis, nanofiltration and electrodialysis are capable of removing all kinds of dissolved solids including arsenic from water. In this process water is allowed to pass through special filter media which physically retain the impurities present in water. The water, for treatment by membrane techniques, shall be free from suspended solids and the arsenic in water shall be in pentavalent form. Most membranes, however, cannot withstand oxidizing agent.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

22. MRT-1000 and Reid System Ltd

Jago Corporation Limited promoted a household reverse osmosis water dispenser MRT-1000 manufactured by B & T Science Co. Limited, Taiwan. This system was tested at BUET and showed a arsenic (III) removal efficiency more than 80%. A wider spectrum reverse osmosis system named Reid System Limited was also promoted in Bangladesh. Experimental results showed that the system could effectively reduce arsenic content along with other impurities in water. The capital and operational costs of the reverse osmosis system would be relatively high.

Reference: M.Feroze Ahmed, http://www.unu.edu/env/Arsenic/Ahmed.pdf

23. Low-pressure Nanofiltration and Reverse Osmosis

Oh et al.(2000) applied reverse osmosis and nanofiltration membrane processes for the treatment of arsenic contaminated water applying low pressure by bicycle pump. A nanofiltration membrane process coupled with a bicycle pump could be operated under condition of low recovery and low pressure range from 0.2 to 0.7 MPa. Arsenite was found to have lower rejection than arsenate in ionized forms and hence water containing higher arsenite requires pre-oxidation for reduction of total arsenic acceptable level. In tubewell water in Bangladesh the average ratio of arsenite to total arsenic was found to be 0.25. However, the reverseosmosis process coupled with a bicycle pump system operating at 4 Mpa can be used for arsenic removal because of its high arsenite rejection. The study concluded that low-pressure nanofiltration with pre-oxidation or reverse osmosis with a bicycle pump device could be used for the treatment of arsenic contaminated groundwater in rural areas (Oh et al., 2000)

Reference: Oh, J.I., Yamamoto, K., K., Kitawaki, H., Nakao, S., Sugawara, T., Rahaman, M.M. and Rahaman, M.H. (2000), Application of low-pressure nanofiltration coupled with a bicycle pump for the treatment of arsenic-contaminated groundwater, Desalination, 132 : 307-314.

24. Arsenic removal tech developed by BCSIR

Scientists have developed a low cost household technology for removal of soluble arsenic from water suitable for use by rural people, reports BSS. The arsenic research group of the Institute of Glass and Ceramic Research and Testing (IGCRT) of BCSIR has succeeded in developing the technology with locally available raw materials after intensive research for eight months. Field test of fresh tubewell water using this technology found that 99.5 per cent soluble arsenic could be removed from arsenic concentration of two milligram per liter. The flow rate is about 6 liter per hour. The available package consists of a filter and 100 packets (1 packet for five litre) flock forming composition for 500 litres of water. The flock forming composition, prepared by mixing a number of chemicals in certain proportions, is added to the arsenic contaminated water followed by stirring and settling. After settling, it is passed through a filter system developed in BCSIR. The cost of a filter is Tk 300 which can purify up to 60,000 litres water.

Source : The Daily Star April 22, 1999

25. Arsenic removal kit

Arsenic removal kit (Trade name 'Arsenil) which can reduce the concentration of arsenic from 1 to 0.02 mg/L. The removal of arsenic is 98 %. The kit is in the form of a pouch containing a chemical composition prepared using charcoal, bentonite powder, sodium chloride, ferrous sulphate and potassium permanganate.

Reference: Dr.S.Sukul, Current Science, Vol.85, No.9, November 2003

26. Edenfern

The edenfern forms the basis of a solar powered (photosynthetic) technology that provides cost-effective, small-scale cleanup of arsenic contaminated soil and surface, ground, and drinking water. Scientists from the University of Florida originally identified this fern, for which Edenspace has licensed exclusive rights for the cleanup of arsenic contaminated soil, sludge and water. The research findings indicates that this fern accumulates an arsenic concentration, in the above ground plant tissue, more than 200-fold higher than any other plant species tested.

27. **Arsenic treatment unit for handpump fitted tubewells developed by PHED, Govt. of West Bengal**

Hand pump attachable arsenic removal plants developed by PHED, Govt. of West Bengal have been installed in the Malda (191 nos), Murshidabad (1129 nos), Nadia (220 nos), North 24 Paraganas (698 nos) and south 24 parganas (100 nos) districts of West Bengal. All the models experimented with have not shown identical performance and the sludge disposal mechanism is yet to be made satisfactory. The maintenance of this unit appears to be complicated and difficult. Community involvement in maintenance has been found to be essential for sustainability of these units.

28. PUR purifier of water

The Scientists of P&G Health Sciences Institute developed this technology. It has been reported that it can reduce the initial arsenic content of 229 ppb to 1.2 ppb. It has been mentioned that the small sachet of powdered product provides precipitation, coagulation, flocculation as well as residual chlorination.

Available technologies for arsenic treatment:

Advantages and disadvantages

Method		[illegible]	Disadvantages
Co-precipitation:		No monitoring of a break through is required. Relatively low cost simple chemicals. Low capital costs.	Serious short and long term problems with toxic sludge. Multiple chemicals requirement Operation requires training and discipline.
	Alum coagulation	Durable powder chemicals normally available.	Efficient pre-oxidation is a must.
	Iron coagulation	More efficient than alum on weigh basis.	Medium removal of As (III).
	Lime softening	Most common chemicals	Re-adjustment of p^H is required.
[illegible] techniques:		[illegible]	[illegible]
	Activated alumina	[illegible]	[illegible]
	Iron coated sand	[illegible]	[illegible]
	Ion exchange resin	[illegible]	[illegible]
	Other Sorbents	[illegible]	[illegible]
Membrane techniques:		• Well defined performance. • High removal efficiency. • No solid waste. • Low space requirement. • Capable of removal of other contaminants, if any.	• High running costs. • High investment costs. • High tech operation and maintenance. • Toxic wastewater. • Re-adjustment water quality is required.
	Reverse Osmosis		Membrane does not withstand oxidizing agents.
	Eleetrodialysis		Membrane does not withstand oxidizing agents.

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	Iron coagulation	More efficient than alum on weigh basis.	Medium removal of As (III).
	Lime softening	Most common chemicals	Re-adjustment of p^H is required.
[illegible]chniques:		No daily sludge [illegible]	Requires monitoring of break through [illegible] Requires [illegible] regeneration [illegible]
	Activated alumina	Relatively well [illegible] and commercially [illegible]	Re-adjustment of pH is required.
	Iron coated sand	Expected [illegible] No regeneration [illegible] required.	[illegible] be standardized. Toxic solid waste.
	Ion exchange resin	Well defined [illegible] and hence capacity.	High cost medium. High tech operation & maintenance. Regeneration creates a sludge problem.
	Other Sorbents	Plenty of possibilities & combinations	Not yet properly studied.
Membrane techniques:		• Well defined performance. • High removal efficiency. • No solid waste. • Low space requirement. • Capable of removal of other contaminants, if any.	• High running costs. • High investment costs. • High tech operation and maintenance. • Toxic wastewater. • Re-adjustment water quality is required.
	Reverse Osmosis		Membrane does not withstand oxidizing agents.
	Eleetrodialysis		Membrane does not withstand oxidizing agents.

C ered population as on 31.3.2004

Total covered population in rural areas through Short term, Medium term and Long term measures is 89.78 Lakhs.
Details are furnished below.

Measures/Schemes	Number	Rural Population Covered (Lakh)
Short term		
1. New hand pump fitted tubewells at deeper aquifer	7971	19.92
2. Ring wells	166	0.41
Total of short term		**20.33**
Medium term		
3. Arsenic Treatment Unit(ATU) with existing hand pump fitted tubewells	2338	5.84
4. Arsenic Removal Plant for existing ground water based Piped Water Supply Schemes	12	1.90
5. New Big diameter deeper aquifer tubewells for existing PWSS	8	1.20
6. New ground water based PWSS	209	39.08
Total of Medium term		**48.02**
Long term		
7. Surface Water Scheme for Malda	1	7.71
8. Surface Water Scheme for South 24 Pgs	1	13.72
Total Long Term		**21.43**
GRAND TOTAL COVERED RURAL POPULATION		**89.78**

This does not contain information on covered population of Urban areas

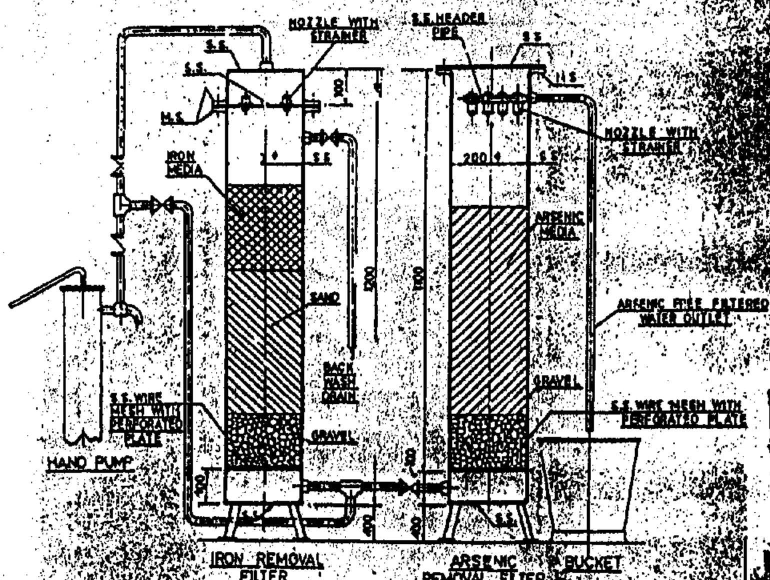
A population of about 90 lakhs is getting arsenic free water which is about 55.77% of the risk population in 75 arsenic affected blocks

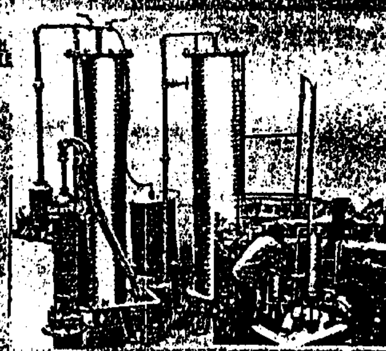
Arsenic Treatment Unit for Hand Pump fitted Tubewells

District	No. Installed as on 31.3.2004
Malda	191
Murshidabad	1129
Nadia	220
North 24 Parganas	698
South 24 Parganas	100
TOTAL	2338

All the models experimented with have not shown identical performance. Sludge disposal mechanism is yet to be made fully satisfactory.

Continuous monitoring of water quality, skilful handling of the tubewell and the Arsenic treatment unit fitted with hand pump fitted tubewell and its maintenance appear to be complicated and difficult. Community involvement in maintenance has been found to be essential for sustainability of these units. Need of another round of exchange of ideas are being felt by the experts and the State Govt. is going to cohost an International Conference on water supply and sanitation to be held at Kolkata.





CHEMICON MODEL ATU

Technologies for removal of excess Fluoride in drinking water

TECHNOLOGY OPTIONS FOR FLUORIDE REMOVAL

Numerous methods have been described employing various materials for the fluoride removal since 1930s. Based on the nature of processes, the defluoridation techniques can be grouped under the following categories

- (i) Adsorption
- (ii) Ion exchange
- (iii) Precipitation
- (iv) Electrochemical method and
- (v) Membrane Technique

Adsorption

1. Wood,
2. Lignite Coal,
3. Bone
4. Petroleum residues
5. Nut shells,
6. Pady husk
7. Avaram bark
8. Coffee husk,
9. Tea waste
10. Jute waste
11. Cocnut shell
12. Coir pith,
13. Fly ash
14. *Carbion,*
15. Defluoron-1, Defluoron-2
16. Activated alumina
17. KRASS,
18. Bauxite,
19. Serpentine
20. Dried and Crushed leaves of following plants: *(Azadirachta indica), pipal (Ficus religiosa) and khair (Acacia catechu willd) trees*
21. Clay minerals
22. Fish bone,
23. Calcite

Ion exchange

1. NCL poly anion resin
2. Tulsion A27
3. Lewatit-MIH-59
4. 4.Amberlite IRA-400
5. Deacedodite FF-IP
6. Waso resin-14 Polystyrene

Precipitation

1. Nalgonda Technique
2. Alum floc blanket method
3. Poly aluminium chloride(PAC)
4. Polyelectrolytes.

Membrane Based

1. Electrodialysis
2. Reverse Osmosis

- The lime dose required to be added is empirically 1/20th that of the dose of alum. Lime facilitates forming denser floc or rapid settling.
- The quantity of alum and lime depend upon the quantity, alkalinity, pH and fluoride content of water. The amount of alum needed increases with alkalinity and initial fluoride concentration.
- The advantages include:
  - (i) Useful at community and household level
  - (ii) Cost effective
  - (iii) Indigenous technology
  - (iv) Low capital cost

- Nalgonda technique is suitable only when the dissolved solids are below 1500 mg/l, total hardness is below 250 mg/l, alkalinity of the water is sufficient and raw water fluorides ranging from 2 to 20 mg/l. Demerits of this method are
  - (i) the large amount of alum needed to remove fluoride
  - (ii) careful pH control
  - (iii) high residual aluminium
  - (iv) needs disposal of large amounts of sludge.
  - (v) Alum dose needs regular calculation

In the case of alum and lime application, the detention time required for complete settlement of all the flocs is about 2 to 4 hours. The capital cost is low and the operational cost is marginal – to defluoridify 20 liters of groundwater (containing 5 mg of fluoride a liter) costs around 6 paise.

Polymeric aluminum compound, poly-aluminium-hydroxy-sulphate(PAHS) is found to require less flocculation time and settling time. The requirement of PAHS to bring down the fluoride content below permissible level is tabulated in Table 4 and 5.Detention time of 20 to 30 minutes will suffice for complete settlement of all flocs. Cost of PAHS is much less than the alum.

ACTIVATED ALUMINA (AA)

- Commonly known as Prasanti technology. In this process, raw water is passed through AA which adsorbs fluoride, passing out defluoridated water
- Advantages include: Usefulness at community and household level, low sludge formation,
- Demerits are cost is inhibiting for villagers, regeneration of AA is problem, operation and maintenance require skilled personnel who are not available in villages
- Some commercially available systems based on this technique are mentioned below:

1. **Satya Sai University for Higher Learning**, Andhra Pradesh has developed kits that cost Rs 35,000 at community level and Rs 1,300-1,700 at household level. Filters can be attached with handpumps or standposts
2. The point of use Domestic Defluoridation Unit (DDU) is easy to assemble and simple to use. **Designed at IIT, Kanpur, under the UNICEF-sponsored R&D project SWACH,** it consists of an upper and a lower chamber. The upper chamber is fitted with a micro-filter with an orifice at the bottom to give a flow rate of about 12 liters per hour. This chamber is charged with 3 kg of activated alumina packed to a depth of 17 cm. A perforated stainless steel plate is placed on top of the activated alumina bed so that the raw water is uniformly distributed. The chamber is covered with a lid. The lower chamber is provided with a tap. An earthen pot can be used as the lower chamber to reduce the initial cost and keep the water cool. To use the filter, raw water is filled in the upper chamber. The water percolates through the activated alumina bed from where fluoride is adsorbed on to the adsorbent. Treated water, collected in the lower chamber, can be drawn whenever needed. DDUs that use activated alumina to rémove fluoride are simple to operate and the medium regeneration procedure does not involve any complicated steps. Studies show that DDUs are an inexpensive method of defluoridation – apart from the initial capital investment of the filter, the cost of defluoridizing 20 liters of groundwater (containing 4 mg of fluoride per liter) is only 17 paise.

3. INDION Domestic Defluoridation Unit INDION Domestic Defluoridation Unit - *Point-of-Use Unit*

- Incorporates 3-stage process based on activated alumina for filtration & fluoride removal.
- The high surface area & larger pore size of the media provides better diffusion.
- The media can be regenerated several times & is re-useable
- The stainless steel unit is corrosion resistant & easy to handle; does not require electricity to operate
- The size of the unit is designed based on UNICEF guidelines.
- An order from NGO Velugu for supply of 1032 domestic defluoridation units for Cuddappa and Nalconda districts in Andhra Pradesh is being worked on.
- Rural Development Engineering Department (RDED), Bangalore placed an order for 10,000 domestic defluoridation units
- based on UNICEF guidelines. UNICEF has also audited our quality management

INDION Community Level Defluoridation Unit

Ion Exchange India Limited has installed and commissioned INDION Power Pump Attachment Fluoride Removal Unit, at village Lamkani, in Akola district of Maharashtra. The raw water with fluoride contamination of 2.34 ppm is pumped from the well through the fluoride removal unit which has a 10 m^3/h flow rate. The treated water is stored in an overhead storage tank from which it is distributed to three villages having a population of around 1000. The treated water has fluoride content of 1.3 ppm, well below WHO limit of 1.5 ppm.

INDION Power Pump Attachment Fluoride Removal Unit

INDION Defluoridation Handpump Attachment
This attachment was developed as a demonstration pilot project at Mangi-kolam site in Yavatmal district in rural Maharashtra for treating ground water fluoride contamination of 8.73 ppm, reducing this to 0.304 ppm. Other pilot defluoridation units were installed at Nanded and Nagpur, subsequent to which 67 defluoridation units were installed at Zila Parishad of Yavatmal.

Case study of field trial
At Methan in Gujarat the INDION fluoride removal plant was supplied in 1997.
In Methan, the fluoride level in the well water source was 2.3 ppm. Villagers were experiencing symptoms of fluorosis. In a unique collaborative initiative between Ion Exchange India, Muniwar Abad Charitable Trust and the village community, a fluoride removal project was set up. Treating the 30,000 litres/day drinking & cooking water requirement of the village at a treatment cost of just **2 paise per litre,** the project helped Methan break free from fluorosis.

(Source:http://www.ionindia.com/company.html)

4. This technique has also been utilized by the IICT (Indian Institute of Chemical Technology) in collaboration with M/s IES India. However on evaluation it was found that although fluoride is removed but alumina is introduced in drinking water.

REVERSE OSMOSIS

- In this process, water is passed through a membrane which blocks fluoride flow, allowing only defluoridated water to pass. 60-litre per day filter costs Rs 20,000 Annual maintenance Rs 3,000.
- The advantage of this technique over other method is that a large variety of membranes are available, no chemicals added and it has high fluoride removal efficiency. However cost is inhibitive for villagers after sales service in villages are generally a limitation in the effective functioning of this technique.

ION EXCHANGE

1. This technique has been extensively been researched upon in India and the commercial model ahs been developed by the **Ion Exchange (India) Ltd**. In this process resin is used to adsorb fluoride from water Capacity ranges from 500 litres per hour to 5,000 litres per hour
2. The **CSMCRI (Central Salts and Marine Chemicals Research Institute)**, Surat has also developed an ion selective resin.
3. This method is useful at community and household level This technique has high fluoride removal efficiency. However the resin has be regularly replaced and large amount of salts are involved in regeneration that makes its usage limited. Besides the same draw back of operation and maintenance exists in this method also like earlier methods

Adsorption Based

Sujal kit developed by the TRDDC (Tata Research Development and Design Centre)

- Adsorption of F on alumina coated RHA (rice husk ash)
- F removal capacity: 10 mg/g of RHA
- Single step filtration
- Bacteria trapping 96±3%
- Turbidity removal 95±3%
- Filter element life 6-8 months
- Low cost of replacement of bed
- Filters made: 16300
- People trained: 415
- NGO trained: 77
- Filter donated: 700
- Training workshop: 30

(Source : http://greenbusinesscentre.com/images/Photos/Dec54.pdf)

Ultra Filtration Based:

The National Chemical Laboratory in has developed a "Desi Filter" based on ultra filtaration.

Technologies for removal of excess Salinity in drinking water

Technologies on Desalination for drinking water

1) *Introduction*

Desalination is a process that removes dissolved minerals (not only limited to salts) from sea water, brackish water or treated waste-water. More than 7,500 desalination plants are in operation world wide, of which 60% are located in the middle East. The world's largest plant in Saudi Arabia produces 128 MGD of desalted water.

In India, various scientific organizations like BARC-Mumbai, CMSCRI-Bhavnagar, BHEL, AMD, NEERI, NIOT, TPL, etc. have got various technologies for desalination. About 150 desalination plants have been commissioned in the country by Reverse Osmosis (RO) process, of which, only 77 have been reported to be functional.

Choice of desalination process/ technology depends upon a variety of factors and is highly site-specific. These are :-

- a) salinity of feed water – lower salinity levels like in in-land brackish water could produce higher conversion/product rates.
- b) Plant capacity – larger plants reduces the cost per unit product
- c) Site conditions – environmental considerations for brine disposal and cost/availability of land for infrastructure
- d) Qualified labour – some of the technologies require atleast semi-skilled and trained labour
- e) Energy costs - low cost electric system and heating steam have strong impact on unit cost of production
- f) Availability/ easy access to membranes, chemicals and spares
- g) O&M costs and easiness of operation
- h) Provision for enhancement of designed plant capacity

2) Technologies for Desalination

A number of technologies have been proved while some newer technologies are in the stage of pilot-testing. Technologies available for desalination include :-

- a) Reverse Osmosis (RO) including Sea-water Reverse Osmosis (SWRO)
- b) Solar stills (SS)
- c) Single stage flash distillation (SSF)
- d) Multi-stage flash distillation (MSF)
- e) Multiple-effect evaporation (MEE)
- f) Thermal vapour compression (TVC)
- g) Mechanical vapour compression (MVC)
- h) Low cost vertical tube evaporators (VTE)
- i) Thermocline desalination or Low temperature thermal desalination (LTTD)
- j) MEE with Absorption heat pump (MEE-ABS)
- k) Combination of the above

In India, under rural water supply programme, only reverse osmosis based desalination plants have only been set-up due to its inherent lower capital cost when compared to other technologies.

3) Reverse osmosis (RO)

In RO, the feed water is pumped at high pressure through permeable membranes, separating salts from the water. The feed water has to be pretreated to remove bio-fouling and scaling. The quality of water produced depends upon the pressure, the concentration of slats in the feed-water and salt permeation constant of the membranes. Product water quality can be improved by adding a second pass of membranes. Multi-media filters to remove sand sediments down to 20 μ size, activated carbon filters to remove excess chlorine, 5 μ size pre-filtration systems, sodium metasulphate for removing excess chlorine residuals, acid/anti-scalant dosing systems are available in the market, and need to be considered on case-specific basis, before RO system is chosen for desalination. 10m³ to 50 m³ per day plants have been installed in India. World-wise, RO plants of capacities ranging from 100 m³ to 94,625 m³/day plants have been commissioned. The product water from RO plants have TDS levels ranging between 30 to 500 mg/l. The conversion rate of product water from feed-water varies between 30-50%, depending upon various factors. The cost of production of pure water is about 20 to 30 paise per litre of water produced in smaller plants (less than 100 m³ per day capacities) to only 3 paise per litre in case of large RO plants, as per information available world-wide.

4) Single/Multi-stage flash distillation (SSF/MSF)

This system are equipped with condenser tube bundles to pre-heat the brine recycle system. These tubes function as condensers/evaporators, where the heating steam condenses inside the tubes and vapour is formed outside the tubes. Depending upon the number of flashes, the process could be termed as SSF or MSF. MEE operates with top-brine temperature of 90-110°C. Smaller systems could be designed on SSF technology with scaling of production invites MSF for economies. The unit cost of production varies between 3.47 paise per litre to 8.28 paise per litre of water/distillate produced.

5) Multi-effect evaporation (MEE)

MEE is also a similar process of condensation but requires a heating device like a boiler or waste-heat from any other sources like thermal plants, etc. Steam extracted from low and medium pressure turbines provides the heat necessary for evaporation. MEE operates with top-brine temperature of 64-70°C. The unit cost of production of MEE systems varies from 3.92 paise to 8.78 paise per litre of water/distillate produced.

6) Thermal vapor compression (TVC)
The process of condensation is similar to other distaillation processes except that requirement of steam is a pre-requisite for the system. TVC has been clubbed

with MEE system for large scale plants for better economies. The unit cost of production of distillate/water is 5.9 paise per litre, as per information available.

7) Mechanical Vapour Compression (MVC)

MVC is distinguished from other distillation processes by the presence of a mechanical vapour compressor., which compresses the vapour formed within the evaporator to the desired pressure and temperature. The system also include plate heat exchangers for pre-heating the feed-water using heat exchangers from the brine blow-down and the distillate product. This system is also based on evaporating effect like MEE. This is a good technology and can be adopted for capacities ranging from 100 m^3/day to about 20,000 m^3/day or more. The cost of production is slightly higher at 22.5 paise per litre of distillate/water produced in case of 100 m^3/day to only 2.07 paise per litre of distillate/water produced in case of 20,000 m^3/day plant.

8) Multiple Effect Evaporators with Absorption heat pumps (MEE-ABS)

When an absorption heat pump is introduced along with the MEE system, performance ratio (mass of distillate produced per kg of heating steam) is found encouraging at 21, which ranges between 8-16 in the conventional MEE system. With inclusion of absorption heat pump and gas turbine to an MEE system of 9600 m^3/day capacity, the unit cost of production of distillate/water produced is only 1.58 paise per litre.

9) Solar Stills

Solar still is basically a large scale shallow water pond of saline water (about 10cm deep) spread over a large surface area and covered with glass cover. The natural sunlight is used for evaporating the saline water and the condensed vapour is collected from the glass-case. Though the O&M cost of such plants is near zero and that no power is required, the system is capital-cost intensive when compared with the product recovery rate and the cost of land required.

10) Low cost vertical Tube Evaporator (VTE)

VTE technology has been devised on a pilot scale by IIT-Delhi, with the funds from a R&D project sanctioned by RGNDWM, Department of Drinking Water Supply. This is basically a MEE technology but synthesized for smaller applications, specifically the rural sector of India. The principle involved is the recycling of latent heat of condensation/vaporizations of water in successive efforts so as to achieve a good performance ratio. An LPG boiler is used for heating the feed-water and with a 6-effect VTE, the unit cost of production of distillate/water is found to be 30-40 paise per litre of water produced at the laboratory conditions. The cost is expected to be around 10 paise per litre of water produced, if bio-mass gassifiers are used in the field. This technology again is site-specific and depends upon available of Prosophis juliflora and Acacia auriculiformis, which are generally the bio-mass used for heating in the boilers. The 6-effect VTE at the lab conditions produced 2000 litres per day of product-water with TDS of 10 mg/l. The cost of the plant was reported to be about Rs 56,000 only.

11) Elements of capital and recurring costs

Capital (direct and indirect costs) include

- a) Well construction
- b) Brine disposal
- c) Land
- d) Process equipment and auxiliary equipment
- e) Buildings
- f) Membranes
- g) Freight and insurance
- h) Construction overheads
- i) Contingency

Annual operating costs include

- a) Electricity
- b) Labour
- c) Maintenance and spares
- d) Membrane replacement
- e) Insurance
- f) Chemicals
- g) Amortization

12) Advantages/Disadvantages of membrane and distillation based technologies

SSF, MSF, MEE, MEE-ABS, MVC, TVC are distillation based technologies while the RO and SWRO are membrane based technologies.

Advantages of RO plants over distillation include ::

- a) feed-water generally does not require heating
- b) lower capital cost
- c) no thermal impacts of brine disposal
- d) fewer corrosion problems, if feed-water is pre-conditioned
- e) lower energy requirements
- f) very high recovery rates
- g) removes unwanted contaminants like trihalomethane present in sea water.
- h) Lesser surface area
- i) Re-mineralization would be required as TDS levels are very low in the product water.

Disadvantages of RO plants over distillation include ::

- a) comparatively lesser potential for economies of scale
- b) RO membranes are very sensitive to turbidity, algae and pH
- c) Biofouling

d) Higher TDS levels in product water when compared to
e) Higher O&M costs
f) Availability of membranes and chemicals
g) Co-generation plants could be extended only for reduction in energy use while this could be extended for captive power generation, air-conditioning, development of near-shore fishery production, etc.
h) RO membranes must be cleaned once in a quarter of a year and must be replaced after 3-5 years.
i) Brine disposal could be detrimental to eco-sensitive zones.

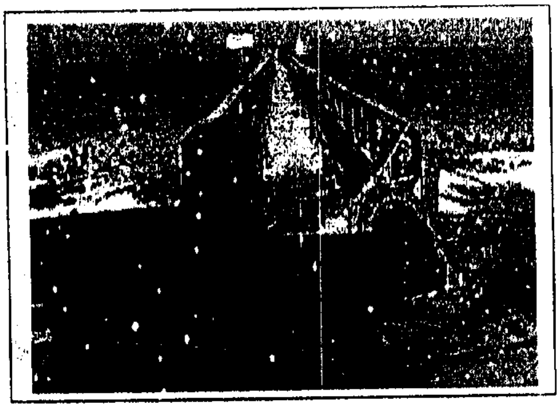
13) Commissioning of Low Temperature Thermal Desalination Plant (LTTD) Plant at Kavaratti

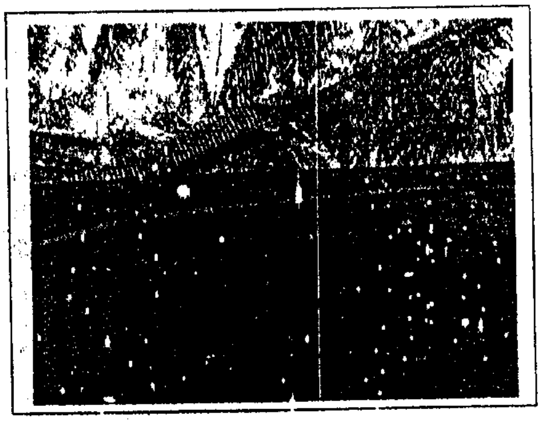
Experimental studies in USA and Japan were conducted to prove the ocean temperature driven desalination technology. A spray flash evaporation system was tested at Saga University, Japan. A 10 m^3/day plant is under experimentation at Institute of Ocean Energy, Japan. Natural Energy Laboratory tested an open cycle OTEC plant with fresh water and power production using ocean temperature difference of 20°C between the warm surface water and deep-sea water, in 1992 at Hawaii islands. It was operational for 5 years and de-commissioned in 1998. Italian Government commissioned a 25 tonnes per hour desalination plant operating between 28-20°C in 1992, which has completed nearly 10 years of commercial production.

National Institute of Ocean Technology (NIOT), Chennai, under the Department of Ocean Development (DoD) had set up an experimental model of 5,000 litres per day capacity using LTTD technology. It was proved that 1% of warm feed water can be converted to fresh water under the conditions of 10-20°C temperature difference. A pilot plant was also set up on a barge up the high-seas off Tuticorin by NIOT and found the results encouraging. Therefore, NIOT had taken an R&D project for commissioning a 100 m^3/day plant at Kavaratti at an estimated cost of Rs 5 crore. The project was funded by DOD, Govt. of India.

Technology of LTTD

The technology basically envisages taking the 15°C temperature difference between the warm surface sea water and the deep-sea cold water. Bathometry studies were done by NIOT to establish the thermocline variations off the coast of Kavaratti island of Lakshadweep, in 2003. Preliminary design was completed by NIOT in consultation with BARC, Mumbai in September 2003. Cold water from 330m depth was envisaged to be brought through a 660m HDPE pipeline. Off the shore to about 300m, a well was constructed where the surface water and deep-sea cold water are being pumped to the Plant located on the shore. The well was connected by a trussle bridge. The warm water was then subjected to low pressure by a vacuum pump and is flashed. The vapour was then subjected to a condenser where deep sea cold water runs through. The condensed water on the outer-surface of the cold water pipes is tapped as the distillate water. About 1.02% recovery was observed at the plant site and the total production of water was 1,02,000 litres on 27/10/05. Electro-chlorination unit is also available to avoid biofouling, though the same is not anticipated. The warm water and cold water were then discharged from the Plant at the shore. The design parameters of this plant are as below :-





Fresh water generation ::	Upto 1.2 lakh litres per day	
Design surface water temperature	::	28°C
Design cold water temperature	::	13°C
Power consumption	::	Rs 60 kW/h
Expected life of the plant	::	25 years
Annual shut down time	::	15 days
Cost of operation	::	14.6 paise per litre
Cost of power	::	3.6 paise per litre
Total cost of production	::	18.2 paise per litre

Capital costs ::

Flash chamber & condenser (SS 316 L shell , Cu-Nl tubes)	::	Rs 110 lakh
Civil construction (including bridge)	::	Rs 112 lakh

Mechanical equipment (with One spare pump for all pumps)	::	Rs 100 lakh
Installation and deployment	::	Rs 88 lakh
Erection & Commissioning	::	Rs 20 lakh
Administrative expenses	::	Rs 10 lakh
Contingency	::	Rs 10 lakh
Total capital cost	::	Rs 450 lakh

Operating costs per year

Equipment maintenance	::	Rs 2.1 lakh
Insurance	::	Rs 1.12 lakh
Manpower (6 people)	::	Rs 8.64 lakh
Consumables & others	::	Rs 5.0 lakh
Interest on working capital	::	Rs 36 lakh
Depreciation on equipment cost	::	Rs 8.4 lakh
Total operating costs	::	Rs 61.27 lakh per year

In addition to the above, other tangible benefits like air-conditioning for 300 rooms and generating annual yield of 33 tonnes of sea food are also applicable from this Plant, apart from having a scope for a captive power plant.

14) In quest of Integrated approach

Selection of technology for desalination, should therefore be considered on case to case basis, on factors described above. Ideal solution for providing safe drinking water in brackish-saline affected habitations is an integrated approach of RO/distillation plant duly augmented by roof-top rainwater harvesting / surface water-based rain-water harvesting structures. Wherever waste heat is available in abundance from thermal power generation plants located on the sea-shore/brackish areas, suitable process of distillation could be adopted to achieve economies of scale. Co-generation activities like power generation (captive power plant, reducing energy consumption, etc.) could be thought of, for overall financial sustainability of the Plant. Wherever alternate sustained availability of surface/ground water is available, this system of providing safe drinking water could be provided to salinity affected habitations, duly considering the economies of operation with technology based solutions.

Technologies for removal of excess Nitrate in drinking water

NITRATE CONTAMINATION OF DRINKING WATER

Methods for removal of nitrates form drinking water

Three possible methods exist for removal of nitrates from drinking water these are:

1. Reverse Osmosis,
2. Ion exchange
3. Distillation.
4. Blending

The utility of these processes has been limited due to their expensive operation and subsequent disposal problem of the generated nitrate waste brine.

This equipment requires frequent, careful maintenance and sampling to achieve and confirm effective operation. Improperly installed, operated, or maintained, equipment can result in nitrate passing through the treatment process and in some cases concentrating the nitrate above the incoming levels.

Nitrate removal Kits/methods available in the Market

ION EXCHANGE RESINS

1. Municipalities in the United States are utilizing triethylamine based nitrate selective resin named DOWEX-NSR1, which has been found to have better selectivity for nitrates as compared to earlier products. This resin is more suited to situations where the ratio of sulphate to nitrate is high which makes it superior to type I or type II strong base anion resins.

The resin is recharged by backwashing with sodium chloride solution. The disadvantages of ion exchange are the high associated cost and the production of highly concentrated brine waste. The backwash solution, which is high in nitrate, must be properly disposed of.

BLENDING/DILUTION OF WATER

Where there is a municipal system, some communities have tried to control high nitrate levels in their central water system by using a "split stream" arrangement.

In this system, a portion of the water is drawn off and treated using an anionic nitrate removal process. The treated water is then blended with the untreated water to dilute the nitrate concentrations. Blended water is not safe for infants but is acceptable for livestock and healthy adults.

Distillation

IN this process the water is boiled and the resulting steam is captured and condensed a cold surface (a condenser). Nitrates and other minerals remain behind in the boiling tank.

Reverse osmosis

This process forces water under pressure through a membrane that filters out minerals and nitrate. One-half to two-thirds of the water remains behind the membrane as rejected water. Higher-yield systems use water pressures of 150 psi.

Charcoal filters and water softeners do not adequately remove nitrates from water. Boiling nitrate-contaminated water does not make it safe to drink and actually increases the concentration of nitrates. Drilling a new well to deeper water with less nitrate may be a feasible remedy in certain areas.

NITRATE REMOVAL KITS AVALIABLE IN INDIAN MARKET

The kit prepared by the Ion Exchange India Limited has been marketing Nitrate Removal Systems for potable water - handpump attachments, community systems which have the following salient features:

1. Water treatment capacity of (500 - 5000 l/h)
2. Nitrates reduced to less than 45 ppm WHO limit
3. Nitrates are adsorbed on the resin
4. Continuous supply of treated water
5. Compact and economical system requiring less chemicals and no electricity.
6. Only sodium chloride is needed for regeneration
7. Sturdy, easy to operate, maintenance free

Demand and Usage of these kits

Two nitrate removal systems of 6 m3/h each were successfully commissioned for NGO CASP (Community Aid & Sponsored Programme) at the community project at Govindpuri, New Delhi, supported by Care India PLUS Project.

Technologies for removal of excess Iron in drinking water

TECHNICAL NOTE ON THE REMOVAL OF IRON IN DRINKING WATER SOURCES

Introduction

Iron is one of the major constituents of the lithosphere and comprises approximately 5 % of it. It is routinely detected in municipal waste effluent, particularly in cities where iron and steel are manufactured. Iron readily complexes with sulphates in the sediments of many surface waters. The primary concern about the presence of iron in drinking water is its objectionable taste.

Iron exists in soils and minerals mainly as insoluble ferric oxide and iron sulphide (pyrite). It occurs in some areas also as ferrous carbonate, which is very slightly soluble. Since groundwater usually contain significant amounts of carbon dioxide, appreciable amounts of ferrous carbonate may be dissolved by the reaction shown in the equation –

$$FeCO_3 + CO_2 + H_2O \longrightarrow Fe^{2+} + 2HCO_3^-$$

In oxygenated water Fe (II) is oxidized to Fe (III). Over the entire pH range of natural water, Fe (II) is thermodynamically unstable in the presence of dissolved oxygen. The reaction rate of ferrous iron is strongly pH dependent. Oxidation of Fe (II) is very slow at pH value below 6. The rate of oxidation increases manifold with the increase in pH.

Iron in groundwater normally remains in dissolved state. When water is drawn through bore wells, oxygen from air gets dissolved in water and iron of ferrous state gets oxidized to ferric state and thus comes out as suspended solids in water. So the water becomes slowly turbid and highly unacceptable from an aesthetic view point.

As far as is known, humans suffer no harmful effects from drinking water containing iron. However, iron interferes with laundering operations, impart objectionable stains to plumbing fixtures and also develop taste problems. Carrying capacity of pipelines in the distribution system is reduced due to the deposition of iron oxide and bacterial slimes as a result of the growth of microorganisms (iron bacteria) in iron bearing water.

Permissible limit of iron in drinking water as per IS 10500 is 1 mg/L, however, the desirable limit is 0.3 mg/L.

Removal of Iron

Oxidation by aeration or use of chemicals like chlorine, chlorine-di-oxide or potassium permanganate followed by filtration alone or by settling and filtration can bring about the precipitation of iron and its removal. Similarly zeolites as well as catalytic oxidation method can also be used for the removal of iron.

Importance of alkalinity

Iron forms complexes of hydroxides and other inorganic complexes in solution with substantial amounts of bicarbonate, sulphate, phosphate, cyanide and halides. Presence of organic substances induces the formation of organic complexes, which increase the solubility of iron. The waters of high alkalinity have lower iron than waters of low alkalinity.

The pH of the solution can be altered by the presence of bicarbonate in the water, the higher the bicarbonate level, the more alkaline the solution may become. In the presence of an alkaline pH i.e in the higher pH iron can be quickly converted from into a ferric(solid) state from ferrous state, which could be then filtered.

Technology adopted by the Govt. of Tripura

Majority of plain areas of Tripura state is supplied water from groundwater sources. In hilly areas, however, water is supplied from surface water sources. The groundwater of Tripura contains very high amount of iron. Recent study conducted by All India Institute of Hygiene & Public Health revealed that iron contents in more than 90% groundwater samples (n=3600) was more than the permissible level (> 1 mg/l). Iron content in groundwater even in the tune of 20 to 25 mg/l could be seen in many habitations. Hence, removal of iron has become essential for most of the groundwater sources. Excess iron can also be removed successfully and economically by adding bleaching powder to iron bearing water if dissolved carbon dioxide is less than 20 mg/L

Removal of iron by the process of aeration-sedimentation-filtration has been found to be most appropriate. However, such process needs meticulous attention in operation and maintenance.

As problem of excess iron in groundwater was well established in Tripura state, the PHED in earlier days adopted the process of aeration, adsorption of iron by charcoal and filtration. But availability of adequate charcoal was posing serious problem to the PHED and accordingly instead of charcoal lime stones were used in modified iron removal plants. As the modified IRP contains aeration (spray aerator) contact bed of lime stones with sedimentation and filtration arrangement, the technique can be well adopted in cases of deep bore well attached piped water supply system in rural areas. Presently, the Rural Development Department is entrusted with water supply also in the villages. The department is supplying water either through spot sources (hand pump attached tube wells) or through piped water supply system for small population (even in the tune of 20 houses). The mini piped water supply schemes are mostly managed by the user groups with active participation. The installation of IRP for mini piped water supply schemes could be considered if community groups are committed to operate and maintain the same and should be based on demand driven approach.

IRP can be installed as hand pump attached model. In the early 90's, considerable number of IRPs were installed under the Mini-Mission Programme funded by Rajiv Gandhi National Drinking Water Mission (RGNDWM) in Tripura state. Unfortunately, due to lack of community participation the programme became totally unsuccessful. Similar situations also prevailed in other states when hand pump attached IRPs were installed with tube wells. As such, unless user communities are committed to operation and maintenance of hand pump attached IRPs, it would be not wise to recommend such types of IRPs in the villages.

There are a good number of mini surface water supply schemes in Tripura. The quality of treated surface water is much better than groundwater as it is free from iron problem. Such type of surface water based piped water supply schemes need to be encouraged in the rural areas where feasible.

Rainwater harvesting in pond, impounding reservoirs etc. could be initiated in rural areas of Tripura state. Such water sources would remain as dedicated water source for drinking, cooking and other domestic work. Harvested rainwater could be treated by using horizontal roughing filter - slow sand filter before use. However, the whole system including operation and maintenance of HRF-SSF unit needs to be managed by the user community.

Domestic candle filters can remove iron effectively provided dissolved iron is oxidized before filtration. In the 70's, the local artisans of Tripura developed a novel domestic filter, popularly known as 'Tripura Filter', using the locally available materials, which has been found to be capable of removing iron from raw water. The Tripura filter has been found to be very popular amongst the people of Tripura as a domestic tool to get rid from iron problem in drinking water. The ingredients of the filters are sandy loam, saw dust and rice husk mixed in fixed proportions in candle form and backed in the kilns.

The domestic type Tripura filter has been evaluated as technically feasible, economically viable and socially acceptable. The candles of Tripura filter are manufactured by using three basic ingredients, viz. rice husk, sand and clay after mixing in definite proportions and subsequent controlled burning. The main filter is comprised of two chambers attached to each other. The top chamber holds the candle and the bottom chamber for storing filtered water. The candle needs cleaning regularly (at least once in a week). Replacement of candles is required after a considerable period of time (usually 2 years). Study of Tripura filters conducted by All India Institute of Hygiene & Public Health revealed that such filters could remove iron at the extent of 96% (average). Influent iron content of up to 38 ppm can be successfully removed by Tripura candle filters. Hence considering all aspects of performance, manufacturing and social acceptability, use of domestic type Tripura filter may be encouraged by all the facilitating agencies so that all categories of rural population can avail of the opportunity to use such type of filters.

In hilly areas of Tripura people are more inclined to drink open water flowing as stream, jhora than groundwater, available if any. The surface water if not properly treated (including disinfection) may pose deleterious effect to the human body. The incidences of water-borne diseases amongst tribal population result in considerable number of deaths. NCL, Pune has also developed a membrane based filter to remove excess iron. This technology is being evaluated by RGNDWM.

Another school of thought was that Membrane filtration in rural set-up and that too in remote places may not be suitable for want of adequate support of infrastructure for proper maintenance. It was observed that use of

Tripura filter (domestic) with additional arrangement of home chlorination may be more suitable in rural set-ups. Study conducted on Tripura filter by AIIH&PH showed that the performance of filters for removal of bacteriological contamination was excellent.

NEERI hand pump attachable iron removal plants

National Environmental Engineering Research Institute (NEERI) has been developed and field tested both for piped water supply and hand pump attachable iron removal plants. These plants have been installed in the iron affected districts in Assam. The evaluation results indicated that the plants are capable of removing iron from 50 mg/L to below 0.3 mg/L.

This plant is a cylindrical system of 1 m^3/hr capacity made from readily available hume pipes or constructed on sites of RCC/ferro cement. The technology involves precipitation of iron by aeration with air then properly settled and finally filtered. This plant comprises of three major components namely aeration chamber, sedimentation tank and filter. Apart from these, it has an arrangement of back wash using partially treated water or treated water. The only maintenance is the backwash whose frequency is nearly one month for iron concentrations above 5 mg/L and nearly two months where iron is below 5 mg/L. The quantity of backwash water available in the plant is about 600 liters and is adequate enough to backwash the filter effectively.

The cost of the iron removal plant has been calculated on the basis of the water demand, capital cost and maintenance, which also include the payment towards the backwash. For a plant comprises of the capacity 1 m^3/hr, 12 operations per day of a population 250 persons the projected cost is Rs.14,900 (as on the year 1990).

Summary of the Technological option for Excess Iron Removal

In the above perspective, recommendations for minimizing iron problem in drinking water as well as removal of bacteriological contamination in drinking water are as follows :-

a) At the first instance, pH and alkalinity should be measured before devising any treatment technology for iron removal. In some cases pH correction may also be required. Moderate alkalinity, high bicarbonate in ferrous form with pH below 6 is ideal for dissolved iron removal by simple aeration. Aeration can be achieved by many techniques like cascading, hydraulic jump creation, vortex motion, catalytic oxidation etc. In predominantly handpump based areas, the normal India Mark II or III may be replaced with force-light pump and connected to a cascade aerator followed by a roughening filter. Alternatively, single-phase motor could be used for spot source iron removal process.

b) In case of deep bore well attached piped water supply schemes, Modified Iron Removal Plant (MIRP) could be installed. However, attention need to be provided by the PHED for better operation and maintenance including housekeeping.

c) Implementation of more mini-piped water supply schemes attached to surface water sources may be encouraged. However, such schemes will require water purification system for up-gradation of surface water quality.

d) Bore well attached mini-piped water supply scheme with community based management system implemented through the Rural Development Department is gaining ground in Tripura. Iron removal plant with aeration-sedimentation-slow sand filtration can be considered for installation provided community groups agree to operate and maintain the same. Alternatively, user-groups may be encouraged to use domestic Tripura filter to get rid from iron problem.

e) Efforts need to be taken to popularize more the use of domestic Tripura filters. Local Panchayats, Sanitary Marts, NGOs may be involved in the programme. An appropriate subsidy may be considered for BPL category of population so that those people can buy the filters at affordable prices. The manufacturing quality of filters must be standardized so that quality goods are sold in the village markets.

f) Rainwater harvesting in pond, impounding reservoirs may initiated in rural habitation. Such reservoirs need to be earmarked as dedicated water source for domestic use. The quality of water need to be upgraded by using horizontal roughing filter - slow sand filter. However, community participation for managing the system must be ensured.

g) In hilly areas, gravity feed water supply schemes, if suitable, must be implemented. Such schemes must have appropriate water treatment systems with proper disinfection. If hilly populations are habitual of using untreated water from hilly stream, jhora etc. then they must be encouraged to use candle filter. in addition, home chlorination (by supplying 100 ml chlorine solution in plastic bottle) system may be in initiated with adequate infrastructural support.

h) Manufacturing of domestic Tripura filter required to be standardized. Various options of use of different materials for manufacturing the domestic filters need to be explored thoroughly. Special emphasis needs to be given on production of lightweight domestic filter so that filters could be carried easily to the hilly areas.

Concluding Remark:-

As per the available resources, excess iron in drinking water may not create any physiological disorders. Though in few sporadic cases, appetite disorders are heard, the fact is not universally established. It is suggested that the Ministry of Health & Family Welfare, Government of India and the State Health Departments may conduct detailed epidemiological studies to ascertain the effect of excess iron intake through drinking water to normal human metabolism activity. It is the aesthetics and odour that prevent people not to drink iron-rich water. At the outset, there is a need for massive awareness generation highlighting this aspect. Secondly, owning up of domestic/community based treatment plants by the local people is the single most important factor for sustainability of the iron removal plants.

LOW COST "TERAFIL" WATER FILTER

1. Application

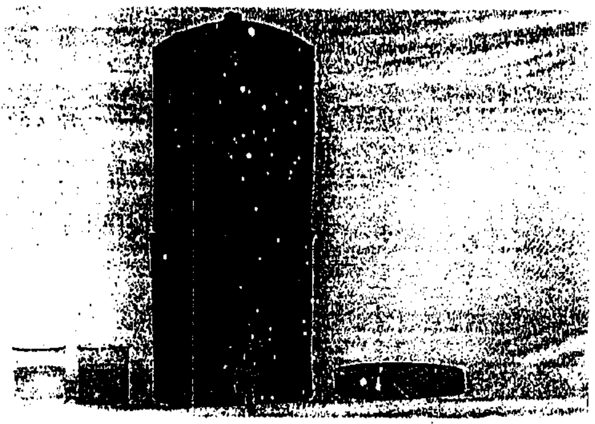
It is used for filtration & treatment of raw turbid water into clean drinking water in a domestic or community scale with minimal expenditure. The raw water is filtered through a Terracotta porous filter disc (TERAFIL). The suspended particles, sediment, Iron & many heavy metals, micro-organism, colour & bad odour are separated from raw water effectively without clogging the core of the TERAFIL. Rate of filtration = 02 to 04 litres/hr in domestic size.

2. Raw Materials

Pottery clay, sand & wood saw dust for preparation of TERAFIL and Terracotta Water Filter.

3. Process Features

TERAFIL is prepared using inexpensive local materials by village potters and cottage industries in rural places. The Terafil is composite of clay membranes, which helps for effective filtration & treatment of raw water into clean drinking water. Terafil is fitted at the bottom of any container to make a water filter. It can be scaled up for community application (50 to1500 litre/hr).



4. Market

10 lakhs/yr

5. Status of Commercialisation

Produced and disseminated by Micro-enterprisers, Govt. agencies, NGOs, International Organization. More than 30,000 units are sold during 2000-2002 in Orissa, India.

6. Equipment and gadgets

Grinding and mixing machine, Queen Kiln, Jigs & fixtures for preparation of TERAFIL.

7. Nature of Enterprise

Cottage Industry

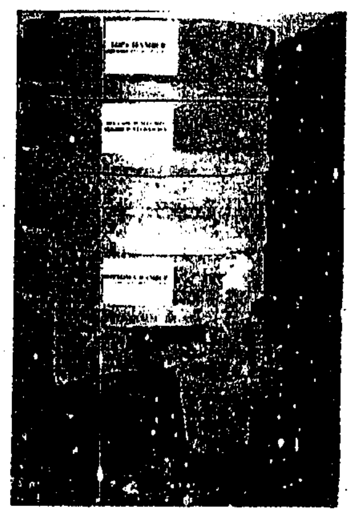
8. Project economics

For production capacity = 2000 units/month (domestic size)

Capital cost	: Rs. 2.00 lakhs
Unit cost of water filter	: Rs.200/-
Unit cost of Terafil	: Rs.25/-
Life of Terracotta Water Filter	: 05 years
Avg. Rate of filtration	: 02 lits/Hr.

9. Technology Package

Know How, Engineering drawings, jig and fixture, training and demonstration for fabrication.



Technologies for disinfection (removal of Biological contamination) in drinking water

DISINFECTION METHODS

Water disinfection can be performed with various disinfants. Chemical disinfectants are chemical substances, which are used to kill or deactivate pathogenic microorganisms.

1. Chlorine

Chlorine is one of the most commonly used disinfectants for water disinfection. Chlorine can be applied for the deactivation of most microorganisms and it is relatively cheap.

2. Sodium hypochlorite

Sodium hypochlorite (NaOCl) is a compound that can be effectively used for water purification. It is used on a large scale for surface purification, bleaching, odor removal and water disinfection.

3. Chlorine dioxide

Chlorine dioxide has been used for years in potable water disinfection (US since 1944). The need arose when it was discovered that chlorine and similar products formed some dangerous DPD's (disinfection by-products) like THM (trihalomethanes).

Since then many UK and US based water companies have started using ClO2. There are however more reasons to use chlorine dioxide:

1. The bactericidal efficiency is relatively unaffected by pH values between 4 and 10;
2. Chlorine dioxide is clearly superior to chlorine in the destruction of spores, bacteria's, viruses and other pathogen organisms on an equal residual base;
3. The required contact time for ClO2 is lower;
4. Chlorine dioxide has better solubility;

5. No corrosion associated with high chlorine concentrations. Reduces long term maintenance costs;
6. Chlorine dioxide does not react with NH_3 or NH_4^+;
7. It destroys THM precursors and increases coagulation;
8. ClO_2 destroys phenols and has no distinct smell;
9. It is better at removing iron and magnesia compounds than chlorine, especially complex bounds;

4. Chloramines

When chloramines are used as a disinfectant, ammonia is added to chlorine treated water. Ammonia is added after chlorine, because this causes CT values to be lower than when ammonia is added primarily. Chloramines are as effective as chlorine for the deactivation of bacteria and other microorganisms, however the reaction mechanism is slower. Chloramines, like chlorine, are oxidators. Chloramines can kill bacteria by penetration of the cell wall and blockage of the metabolism. Monochloramine is the most effective disinfectant. It reacts directly with amino acids in the bacterial DNA. During deactivation of microorganisms chloramines destroy the shell which protects a virus. When the pH value is 7 or higher, monochloramine is the most abundant chloramine. The pH value does not interfere with the effectiveness of chloramines.

5. Hydrogen peroxide

Among other applications, hydrogen peroxide is used as a disinfectant. It is used to treat inflammation of the gums and to disinfect (drinking) water. It is also used to combat excessive microbial growth in water systems and cooling towers.

In the United States, hydrogen peroxide is used more and more frequently to treat individual water supplies. It is used to prevent the formation of colors, tastes, corrosion and scaling by pollution degradation (iron, manganese, sulphates) and micro-organism degradation. Hydrogen peroxide reacts very fast. It will than disintegrate into hydrogen and water, without the formation of byproducts. This increases the amount of oxygen in water.

The disinfection mechanism of hydrogen peroxide is based on the release of free oxygen radicals:

$H_2O_2 \rightarrow H_2O + O_2$

Pollutions are decomposed by free oxygen radicals, and only water remains. Free radicals have both oxidising and disinfecting abilities. Hydrogen peroxide eliminates proteins through oxidation.

Peroxides such as hydrogen peroxide (H_2O_2), perborate, peroxiphosphate and persulphate, are good disinfectants and oxidisers. In general these can adequately remove micro-organisms. However, these peroxides are very unstable.

Perborates are very toxic. Peracetic acid (PAA) is a strong acid. It can be very agressive in its pure form. Stabilised persulphates can be used to replace chlorine for wastewater treatment.

6. Copper-Silver Ionization method

Electrically charged copper ions (Cu^{2+}) in the water search for particles of opposite polarity, such as bacteria, viruses and fungi. Positively charged copper ions form electrostatic compounds with negatively charged cell walls of microorganisms. These compounds disturb cell wall permeability and cause nutrient uptake to fail. Copper ions penetrate the cell wall and as a result they will create an entrance for silver ions (Ag^+). These penetrate the core of the microorganism. Silver ions bond to various parts of the cell, such as the DNA and RNA, celular proteins and respiratory enzymes, causing all life support systems in the cell to be immobilized. As a result, there is no more celular growth or cell division, causing bacteria to no longer multiply and eventually die out. The ions remain active until they are absorbed by a microorganism.

7. BOILING WATER

Place water in a container over heat. Bring it to the boiling point. Hold it at this temperature for 15-20 minutes. This will disinfect the water. Perhaps you have used this technique after a flood or when a water main has burst as an emergency aid. Boiling water is an effective method of treatment because no important water-borne diseases are caused by heatresisting organisms.

8. ULTRAVIOLET LIGHT

The use of ultraviolet light is an attempt to imitate nature As you recall, sunlight destroys some bacteria in the natural purification of water. Exposing water to ultraviolet light destroys pathogens. To assure thorough treatment, the water must be free of turbidity and color. Otherwise some bacteria will be protected from the germ-killing ultraviolet rays. Since ultraviolet light adds nothing to the water, there is little possibility of its creating taste or odor problems. On the other hand, ultraviolet light treatment has no residual effect. Further, it must be closely checked to assure that sufficient ultraviolet energy is reaching the point of application at all times.

9. Ozone

Ozone has been used for disinfection of drinking water in the Municipal Water Industry in Europe for over 100 years and is used by a large number of Water Companies, where ozone generator capacities in excess of 100 kg/h are common.