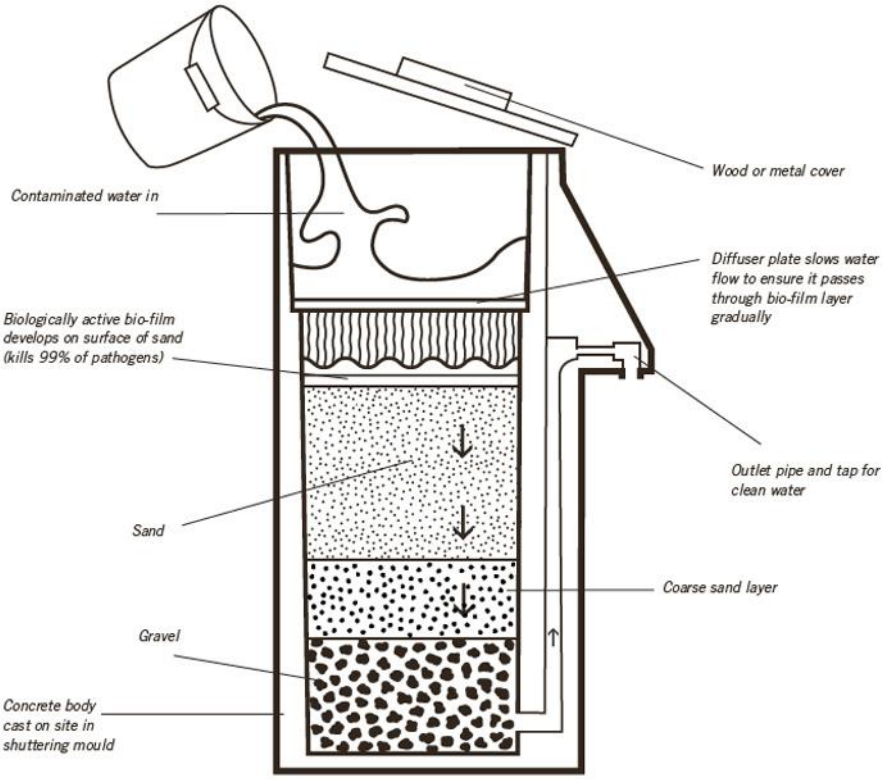
Innovative Techniques and Technology Solutions to Water contamination in Odisha State



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GLOSSARY

AMD	Atomic Minerals Directorate
AP	Andhra Pradesh
BARC	Bhabha Atomic Research Center, Mumbai
BHEL	Bharat Heavy Electronic Limited
BIS	Bureau of Indian Standards
CDC	Center for diseases Control and Prevention
CGCRI	Central Glass and Ceramics Research Institute
CSDW	Children Safe Drinking Water
CSIR	Central Scientific and Industrial Research
CSMCRI	Central Salt &Marine Chemicals Research Institute, Bhavanagar
F	Fluoride
Fe Co3	Ferrous Carbonate
Fe	Iron
Fe2	Ferrous Iron
Fe3	Ferric Iron
H2S	Hydrogen Sulfide
HP	Hand Pump
HWTS	Household Water Treatment and Storage
IMMT	Institute of Minerals and materials Technology
IRP	Iron Removal Plant
IT	Information Technology
ITES	Information Technology Enabled Services
MDWSS	Ministry of Drinking Water Supply and Sanitation
N HCL	Nitrogen Hydrochloride
N	Nitrate
NEERI	National Environmental Engineering Research Institute
NIOT	National Institute of Ocean Technology
ORS	Oral Rehydration Solution
OXFAM	Oxford Committee for Famine Relief
PET	Poly Ethylene Terephthalate
POU	Point of Use
RHA	Rise Husk Ash
RO	Reverse Osmosis
SEUF	Socio Economic Unit Foundation, South India
TCS	Tata Consultancy Services
TDS	Total Dissolved Solids
TERI	The Energy and Research Institute
TPL	Tamil Nadu Petrochemicals Limited
U-V	Ultra Violet
WHO	World Health Organisation

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Introduction

India faces an enormous challenge in providing its citizens with clean potable water free from pathogenic bacteria, viruses, and cysts which cause diseases such as diarrhoea, cholera, typhoid, and amoebiasis. It is estimated that about 10 million illnesses and 700,000 deaths in India could be attributed to diarrhoea of which 400,000 are children under the age of five. Moreover, due to over exploitation of ground water, the levels of mineral contaminants such as arsenic and fluoride in water drawn from wells have increased dramatically. High levels of arsenic in drinking water cause serious and sometimes fatal health problems such as nervous dysfunction, cancers of the bladder, skin, kidney, liver and hyperkeratosis of the palms and feet. Consumption of water that contains high levels of fluoride causes dental as well as skeletal fluorosis —a crippling bone disease causing severe deformities in adults as well as children.

Odisha State faces all the above problems, with the exception of Arsenic contamination that has not yet been identified in the state. This report identifies the current known innovative techniques and technologies that can be used to address these particular problems. This report also acknowledges and draws on content developed jointly by Ministry of Drinking Water Supply and NEERI (Nagpur) in the recently published Handbook on Drinking Water Treatment Technologies (2011).

Household water treatment and storage

Over 5 billion people worldwide are exposed to unsafe water. Given the obstacles to ensuring sustainable improvements in water supply infrastructure and the unhygienic handling of water after collection, household water treatment and storage (HWTS) products have been viewed as important mechanisms for increasing access to safe water. Although studies have shown that HWTS technologies can reduce the likelihood of diarrhoeal illness by about 30%, levels of adoption and continued use remain low. An understanding of household preferences for HWTS products can be used to create demand through effective product positioning and social marketing, and ultimately improve and ensure commercial sustainability and scalability of these products. In 2008, a conjoint analysis survey of a representative sample of households in Andhra Pradesh (AP), India was done to elicit and quantify household preferences for commercial HWTS products. This survey indicated that the most important features to respondents, in terms of the effect on utility, were the type of product, followed by the extent to which the product removes pathogens, the retail outlet and, the time required to treat 10 L. Holding all other product attributes constant, filters were preferred to combination products and chemical additives. Department stores and weekly markets were the most favourable sales outlets, followed by mobile salespeople. In general, households do not prefer to purchase HWTS products at local shops[1].

Growth in purchase power, non-availability of clean potable water, and the introduction of innovative, affordable chemical/resin-based products have given the Indian point-of-use (POU) water treatment systems market a significant boost. The residential water treatment systems market is in the growth stage in India as urban lifestyles evolve in tandem with increasing globalization and the rapid pace of development of the IT/ITES industry. Extensive marketing efforts by product suppliers have helped expedite awareness on the detrimental effects of water contamination.

New analysis from Frost & Sullivan - Strategic Analysis of the Point-of-Use (POU) Water Treatment Systems Market in India, finds that the market earned revenues of over INR 16,500 million in 2008 and estimates this to reach INR 50,758 million in 2013[2].

Treatment of contaminated drinking water

Water treatment should be the last resort at community and household level in rural areas of India. Location, development and proper protection of uncontaminated drinking water sources should be the priority in all locations. In rural villages, advanced and complex water treatment technologies are rarely viable and sustainable solutions. For a water treatment technology to succeed, where the provision of drinking water from an uncontaminated source is not feasible, it should be simple, easy to operate and maintain, be affordable and not rely on external support and should utilise local resources. Use of proven traditional methods should be preferred.

Community mobilisation, building of ownership, addressing of socio-cultural issues, creation of awareness and effective capacity building are pre-requisites for successful implementation of community based water treatment systems. Without these actions the systems will fail. As an alternative, the community should be introduced to contracting of operation and maintenance services that will assure better long term sustainability.

Conventional water treatment technology follows through the processes of flocculation, sedimentation, coagulation, filtration and disinfection. Innovative techniques utilise some or all of these methods, often using surprising media. Removal of the heavy metal, lead, from drinking water normally requires a complex treatment process. However, it has been found that ground dried banana skins, when placed into a filter as the filter medium, removes lead contamination from drinking water.

The key contaminants in drinking water in Odisha are bacteriological, fluoride, iron, nitrate and salinity.

[1] Research Triangle Institute (USA) 2012
[2] Frost & Sullivan 2012

Bacteriological

Bacteriological contamination in drinking water usually arises through poor hygiene and sanitation within the community. Groundwater can be contaminated by the practice of open defecation and through bad drainage where rainwater carries contamination from the surface into the ground. This is why the incidence of water borne diseases escalates just after the start of monsoon.

Surface water can similarly be contaminated at any time by open defecation within the catchment area and drainage discharges into the surface water storage. Bathing and clothes washing, cleaning cattle and vehicles in surface waters can all introduce contamination, much of which will be bacteriological.

Drinking water taken from these unprotected sources can therefore become the source of diseases. Even if a source is protected and known to be pure, there is no guarantee that water consumed from such a source remains pure. Bad hygiene practices, poor storage and lack of understanding can turn pure water into a poison very easily within the home or during collection.

The need for bacteriological treatment is not evident just from looking at the water. Simple indicator tests, such as the H_2S vial, which is appropriate for a rural setting, are not in common use. This means that water borne diseases, and particularly diarrhoea, have become accepted as “usual” and are treated by use of ORS (oral rehydration salts) without the source of contamination having been identified and tackled. Simple techniques such as sanitary survey around a contaminated source can lead to identification of the source of contamination and enable source cleaning action to turn the source into a pure one. Bacteriological contamination is a very transient situation and the best solutions involve the community in using improved hygiene and sanitation practices. The use of simple filtration and chlorination in the home are additions that ensure the family is given more protection and if they become standard practice the incidence of disease will reduce dramatically.

Fluoride

Fluoride (F) as a groundwater contaminant is a worldwide problem. The source of this contamination is natural, depending on climate, rock type and geochemical conditions that are favourable to the release of fluoride from aquifer rocks.

It is estimated that up to 60 million people are reported to be affected with dental, skeletal and/or non-skeletal fluorosis in India, the extent of fluoride contamination varying between 1.0 to 48.0 mg/l. Fluoride in groundwater is increasing in India at an alarming rate as groundwater is increasingly exploited.

There are reports of fluoride contamination in ground water in Boden block of Nuapada district, Bhapur and Sarankul block of Nayagarh district, Bolagarh block of Khurda district and part of Bolangir district. This has resulted in fluorosis in these areas. The

State government is taking steps to identify the chronically affected areas and to provide piped water supply to counter the problem[3].

Central Ground Water Board has estimated from its limited ground water sampling points that parts of up to 11 of the Districts of Odisha have fluoride contamination above the permissible limit of 1.5 ppm[4]. There is, however, much spatial variability and a lack of complete ground water testing information. The geology of Odisha does contain strata where parent rocks may hold potential for fluoride to contaminate drinking water. This should be the starting point for more detailed survey of drinking water sources.

Iron

Iron (Fe) is one of the most abundant metals in the Earth's crust, the major constituents of the lithosphere and comprises approximately 5% of it. Iron readily complexes with sulphates in the sediments of surface waters. The primary concern about the presence of iron in drinking water is its objectionable taste.

Iron occurs naturally in groundwater in a soluble form as ferrous iron (Fe_2) or the more complex form as ferric iron (Fe_3). It also occurs as ferrous carbonate, which is slightly soluble and since groundwater contains significant amounts of carbon dioxide, appreciable amounts of ferrous carbonate ($FeCo_3$) may be dissolved. In oxygenated water Fe(II) can become Fe(III). This can happen when groundwater is drawn and kept standing in air, resulting in a brownish precipitate in the water. Iron can also have an industrial origin and result from corrosion. In acid waters the mechanism of handpumps can be a source of iron contamination.

Iron interferes with laundering operations, imparts staining, affects cooking of rice and makes bathing unpleasant. The desirable level of iron in water is less than 0.3 mg/l and the permissible level is 1.0 mg/l. High levels of iron do cause gastrointestinal distress.

Nitrate

Nitrate (N) is a contaminant in most natural waters at moderate concentrations that do not cause health impacts. However, recent studies have shown increasing levels of nitrate in drinking water in many places in India. This is largely caused by the increasing use of chemical fertilisers, uncontrolled animal feeding operations as well as use of pesticides and industrial process waste contamination of water courses.

High nitrate intake can cause abdominal pains, diarrhoea, vomiting, hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions, respiratory tract infections and changes in the immune system[5]. Nitrate has been implicated in methemoglobinemia or blue baby syndrome in infants less than 6 months of age. BIS has stipulated a desirable standard for nitrate of 45 mg/l compared to the WHO guideline value of 50 mg/l.

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[3] State of the Environment Report, GoO Chapter 5

[4] CGWB State Profile of Orissa

[5] MDWSS/NEERI Handbook on Drinking Water Treatment Technologies 2011

Salinity

High levels of salinity are becoming evident on a larger scale along the coastal plains of many states of India. Odisha is no exception and faces an escalating problem as agricultural demands and increased use of water by the population encourages seawater intrusion and deterioration of the quality of the coastal aquifers. People will tolerate salinity up to levels of 2000 mg/l where no alternative exists but this is not good for their health, although it is accepted as the official permissible limit. TDS levels of 500 mg/l are normally accepted as a desirable limit.

Desalination is a process that removes dissolved mineral salts from feed water to reduce the totally dissolved solids (TDS) to acceptable levels. In India various organisations such as BARC-Mumbai, CMSCRI-Bhavnagar, BHEL, AMD, NEERI, NIOT and TPL have developed technologies for desalination. About 150 desalination plants have been commissioned in the country using reverse osmosis technology, but of these only about 50% are reported to be functional[6].

In India, under the rural water supply programme, only reverse osmosis based desalination plants have been constructed due to lower capital costs when compared to other technologies such as Electrodialysis and industrial scale distillation processes. Cost of pure water production is as low as 3 paise per litre in the case of large plants, but these require sophisticated maintenance that can only be contracted from major suppliers.

Innovative solutions to Water Quality problems

Bacteriological

Treating drinking water at the household level is one of the most efficient and cost-effective ways of preventing water borne diseases. While household water treatment offers superior health gains, the economic advantages over more conventional improvements in water supplies are equally compelling.

The cost of implementing various levels of water quality improvement varies is indicated in the following table[7]:

	Water treatment method	**Cost per person/year (Rs.)**
1.	Solar disinfection (SODIS)	32
2.	Chlorination	33
3.	Ceramic filter	151
4.	Combined flocculation/disinfection	247

Boiling

Boiling is the oldest and most common practiced household water treatment/disinfection method. Boiling water for 5-10 minutes will completely disinfect it and kill all the bacteria and viruses that cause water borne diseases. If there is any

[6] MDWSS/NEERI Handbook on Drinking Water Treatment Technologies 2011
[7] MDWSS/NEERI Handbook on Drinking Water Treatment Technologies 2011

doubt about the quality of drinking water from a particular source the users should be advised to boil their drinking and cooking water needs before consumption.

SODIS

Solar disinfection is an ideal method for treating household drinking water at virtually no cost. The method involves storing drinking water in clean PET bottles and exposing them to at least six hours of strong sunlight. On cloudy days the time should be extended. The treatment is given by the exposure to ultra-violet (U-V) radiation in sunlight and the heat generated. Very turbid water cannot be treated this way without first filtering the water. The bottle should not be of greater diameter than 100mm and should be transparent, with no labels and colourless.

A U-V light source is a common constituent of proprietary household water treatment units that are currently too expensive for use in rural households. These require electricity and have other elements (such as carbon filters and reverse osmosis units) that increase the cost.

Simple filtration

Simply filtering drinking water through a folded cotton sari cloth can have a dramatic impact on both turbidity and the removal of helminth ova and larger protozoas. This should be a standard household practice before any other form of treatment is attempted.

Tap in pot

Where drinking water is stored in a household it is often done in a wide mouthed pot that allows contamination to enter during the action of dipping a drinking vessel or through dust in the air. Having a narrow mouth storage vessel helps reduce contamination but a more effective solution is to have a tap in the storage vessel, just above the base of the vessel and a covered mouth. This removes contamination through dipping completely.

Chlorination

Chlorine is one of the most used and versatile chemicals for water treatment and disinfection, as pure chlorine or a chlorine derivative (such as chlorine dioxide, sodium and calcium hypochlorite). It will deactivate most bacteria and viruses and is low cost. However, it is not effective in removing the more resistant helminths and protozoa that are removed by careful filtration in the home (see above). Chlorination can also produce several potentially harmful by-products. In an emergency situation/outbreak its use will be the primary treatment.

Chlorination is used in piped water systems and is effective if some residual chlorine is maintained at point of use (0.5 to 1 ppm). This is then available for action within any home storage utensil. It is also used to provide new pipelines with cleansing before commissioning.

Purification of Drinking Water by Combined Treatment with Natural Coagulants and Solar Disinfection

Using natural materials to clarify turbid water is a technique that has been practiced for centuries and the seed materials used have been found to be effective. From the present research 10 litre turbid water treatment unit for surface water having various turbidity has been designed. All the seven agro based seeds: Molinga oliefera (Drumstick), Strychnos potatorum (Nirmali), Zeemays (Maize), Coccinia Grandis (Dondakaya), Abelmoschus esculentus (Lady finger), Pisum sativum (Peas), Phaseolus vulgaris (Beans) are non-toxic and effective coagulant aids useful for removing turbidity and bacteria from water. The cost of solar disinfection is negligible as it is a natural source. The cost of seed treatment is very low, in some cases negligible. It is cheap and easy methods at house hold as well at community level for developing countries. The low volume of sludge precipitated was found biodegradable and hence environmentally not harmful.

Microbiological treatment with rice husk ash (RHA) filters

Rice husk ash obtained from rice husk stove can be used for treatment of water. It has been reported that absorption efficiency of RHA is 78% for microbial contaminants.

Water Purification Using Rechargeable Polymer Beads

'Halo-pure' is a technical advance in the development of an entirely new biocidal medium in the form of chlorine rechargeable polystyrene beads that is based on patented chemistry inventions from the Department of Chemistry at Auburn University[8]. The discoveries were the natural but creative outcome of a series of studies, covering more than a decade of research, focused on stabilizing chlorine on water insoluble, synthetic polymer surfaces.

The fundamental principles of the technology are deceptively simple to understand, although their incorporation into a reliably reproducible and practical medium for water sanitation has taken years of intense effort and research. Porous polystyrene beads are similar to those used for water softener resin beds, are modified chemically so as to be able to bind chlorine or bromine reversibly in its oxidative form. All that is required is enough free chlorine to surround the binding site. Almost no free chlorine is released when the beads are placed into the water flow. Typical levels range from 0.05 ppm to 0.20 ppm free available chlorine. This is not enough to kill anything without lengthy incubation.

Tata Consultancy Services filters

Researchers at Tata Consultancy Services Innovation Labs are developing water purification technologies appropriate for India that do not require electricity or regular user intervention. TCS has developed counter-top filters-one of the world's most economic household water purifiers, for removal of contamination from water. The key ingredient of the rural and urban household level filter is a matrix of pebbles, cement, and rice husk ash, a by-product of the paddy industry which, while had little or no value to the rice growers, was a highly effective filtration medium. The adsorbent capacity of rice husk ash emanates from its microstructure which consists of porous silica and carbon, forming an intricate network of microscopic holes and channels. In 2006, the

[8] Dunk et al 2005

team developed a novel method for modifying the surface of rice husk ash to incorporate millions of silver nanoparticles into its pores resulting in a material that had greatly enhanced bacteria-killing performance. This material was then incorporated into a compact cartridge which forms the heart of *Nanotech Water Purifier. The *Bulb is capable of purifying 3,000 litres of water without clogging or losing effectiveness and incorporates an indigenous Fuse to shut the flow of water when the bulb reaches the end of its useful life.

Household biosand filter

Bio-sand filters are a modification of slow sand filters and are appropriate as household scale systems. These filters consist of layers of sand and gravel through which filtration of water takes place. They do not require any chemical pre-treatment of water. Microorganisms in water get absorbed onto the fine sand particles and develop into a highly active food chain, called the Biological Layer. This biological layer traps and feeds on the microorganisms and contaminants in the water. Water is poured into a diffuser on top of the filters and travels slowly through the sand bed and several layers of coarse sand and gravel, and collects in a pipe at the base of the filter.

These filters are easy to use and maintain. However, they require regular cleaning in order to avoid clogging. Biosand filters are effective in the removal of pathogens, moderate levels of turbidity and also, odour and colour. These filters have a high flow rate and can be constructed of local materials. However, they are not effective in highly turbid waters, and may also require some post- disinfection since they are not very effective in the removal of viruses.

Chlorfloc

Chlorfloc is a flocculating product used for removing turbidity and for sanitizing water. Chlorfloc tablets contain flocculating agents (e.g., aluminium sulphate) to clarify the water and sodium dichloroisocyanurate, a form of chlorine to provide disinfection. These tablets are easy to use, non-hazardous, easily transported, and disinfect water within minutes. . This product has been used during flood disasters in Africa, South America and Southeast Asia, and by several military institutions worldwide. US Army and SA Defence Forces have been using the product for the past 15 years. Independent studies have also been conducted by OXFAM, who recommend the product for safe drinking water in emergency situations.

Household Point of Use Systems

As the educated middle-class population in India is steadily growing, the purchasing power is also increasing. Companies have used this as an opportunity to sell HWTS systems across the country. In fact from 1995 to 2005, the annual unit sales of HWTS products grew threefold, to almost 3 million units. The systems developed for this class of the population includes high-end combined filtration and ultraviolet (UV) disinfection systems that cost about $150. In the recent past these companies have introduced Reverse Osmosis (RO) systems in the Indian market.

Initially priced at about $300, these state-of-the-art treatment units have been a great success too, and with cheaper Chinese versions of these systems becoming increasingly available, the price to the consumers is also coming down at a fast rate.

Additional salient facts regarding the point of use treatment system market in India are presented below:

- Nearly one-fifth of India's population uses folded cloth filters to remove sediments and larger contaminants.
- In 1999, more than 8% of India's households purified water through boiling, and almost 6% were using candle filter drip pots.
- Recent studies suggest that 20% of urban and peri-urban residents boil their water, 34% filter through cloth or net, 21% use a candle filter, 13% have a high-tech filter, and 9% have a tap filter.

In the past two to three years a paradigm shift in the Indian HWTS markets has been observed, where the same manufacturers have come up with a portfolio of low-cost treatment systems. The target population for these products are the poor and lower middle classes hence these systems are priced anywhere between US $ 20-40.

Fluoride

Defluoridation of drinking water is the only practicable solution to overcome excessive fluoride, where an alternative source is not available. While a number of technologies, based on industrial level processes such as adsorption and ion exchange in filter systems, coagulation and precipitation and membrane filtration have been developed and tested, sustainable implementation has rarely been achieved in rural communities. Failure here is due to a number of factors including a lack of technical support and material supply, costs, lack of proper maintenance and monitoring but also the perceived deterioration of water quality as a result of the treatment process. The following are some of the innovative techniques currently being researched or made commercially available:

Sri Lankan Domestic System

Freshly fired brick pieces are used in Si Lanka for the removal of fluoride in domestic defluoridation units. The brick bed in the unit (an 8 inch dia tube of pvc or cement concrete pipe) pipe is layered on the top with charred coconut shells and pebbles. Water is passed through the unit on an upflow mode. The unit has to be reconstituted with fresh bricks after 25-40 days when withdrawal has been about 8 litres of treated water per day and raw water fluoride concentration was 5 mg/l.

Tamarind Gel and Seed

The concentration of fluoride from a solution of sodium fluoride of 10 mg/l could be reduced to 2 mg/l by the addition of tamarind gel alone and to 0.05 mg/l by the addition of a small quantity of chloride with the gel.

Tamarind seed can also be used for sorptive removal of fluoride. It is a household waste item in many parts of India after removing tamarind pulp for food preparation. It removes maximum quantities of fluoride at normal pH for water (7.0). The material can be regenerated using a weak solution (0.1) N HCl.

Phytoremediation based removal of heavy metals

Phytoremediation is an emerging, plant based technology for the removal of toxic contaminants from water and soil. The groundwater of the two districts in Kerala

(Palakkad and Alleppy) showed high fluoride content. It has been reported that plants like Ramacham, Tamarind seed and clove were efficient in the removal of fluoride[9].

The plant materials such as bark of *Moringa olifera* and *Emblica officinalis*, the roots of *Vetiveria zizanoides* and the leaves of *Cyanodon tactylon* are good plant agents for defluoridation.

Rice husk ash (RHA) filtration

Rice husk ash obtained from a rice husk stove can be used for treatment of contaminated water. It has been reported that absorption efficiency of RHA is 60%, 30% and 78% for iron, fluoride and microbial contamination, respectively.

TERI defluoridation unit

The Energy and Resources Institute (New Delhi) carried out a study to link community effort to solving the fluoride problem. The designed units consist of two buckets equipped with taps and a sieve on which a cotton cloth was placed. Known concentrations of alum and lime were added to the raw water and at the same time, and dissolved by stirring manually. The villagers were trained to fast stir for 1 minute followed by slow stirring for 5 minutes. The flocs formed were allowed to settle for an hour and the raw water was passed through the sieve into the second bucket, which stored the treated water for use.

PUR sachets

More than 2,000 children die every day from diseases caused by unsafe drinking water. To help address this, a USA based company developed a Purifier of Water in collaboration with the U.S. Centres for Disease Control and Prevention (CDC). P&G Purifier of Water is a 4g sachet of powdered ingredients that make 10 litres of contaminated water potable through coagulation and disinfection. It uses the same approach and ingredients as many municipal water-treatment facilities — the two primary components are ferric sulphate, a well-known and widely used coagulant, and calcium hypochlorite, a disinfectant. Through extensive lab and field testing, the technical efficacy of this product has been demonstrated to be robust, as judged by its ability to eliminate turbidity, chlorine-resistant parasites, viruses, bacteria and pollutants like fluoride.

Five clinical studies were conducted with the CDC and Johns Hopkins Univ. to prove the product's efficacy. These studies, involving more than 26,000 people, were conducted in four different countries and in a broad range of settings. They looked predominately at the reduction in the incidence of diarrhoea when people were provided water treated with PUR Purifier of Water (compared to their normal habits). The results of these studies showed that the P&G packets were highly effective and led to an average 50% reduction in the incidence of diarrhoea and up to 90% reduction.

Since 2004, the US-based company and their CSDW partners have provided more than 500 million sachets — enough to purify 5 billion litres of water. Efforts in this area are continuing, and the Compnay has committed to saving one life every hour in the

[9] Department of Science and Technology Annual Report 2012

developing world by delivering more than 2 billion litres of clean drinking water each year by 2020.

Auroquasafe

'AuroAquasafe' is a powdered mixture that removes arsenic, iron, fluoride, pathogenic organisms and suspended solids rendering contaminated water into safe drinking water. It has been developed by 'Environmental Monitoring Service' laboratory in Auroville, Tamil Nadu, India. 'AuroAquasafe' contains a chlorine compound, aluminium salts that act as coagulants and other additives that provide a good coagulation and flocculation process for water treatment. AuroAquasafe can reduce fluoride contamination from 7 mg/l to less than 1.5 mg/l.

'AuroAquasafe' also removes microorganisms by dual action: By precipitation due to the coagulation/flocculation process and by disinfection with NaDCC (sodium dichloroisocyanurate). After 30 minutes of waiting after treatment the residual chlorine concentration reaches very low concentrations (<0.5 ppm) and therefore does not impart a bad taste or odour to the treated water.

The AuroAquasafe system uses a two bucket process with a cotton filter cloth. The pH of the raw water for effective removal of fluoride should be in the range of 6.0-8.0.

Chemo defluoridation technique of NEERI (Nagpur)

Salts of calcium and phosphorous have been used by NEERI to reduce raw water fluoride concentrations from 5-10.0 mg/l to <1.0 mg/l. After about 20 minutes of mixing with the raw water the resultant liquid is allowed to flow by gravity into a sand filter at the rate of 300-400 ml/minute. Treated water is collected in a storage bucket. After 1-2 months of operation the choked filter is cleaned by removing the top sand layer and its cloth liner, which can be washed in a bucket. The cloth is replaced and covered with a fresh layer of sand and the filter is ready for use again. Performance has been tested in 70 units in Yavatmal District of Maharashtra. The palatability of the water is not affected, as is a problem in the well-known, but now abandoned, Nalgonda System.

Solar Distillation

Many organisations in India have developed and put into use household level solar distillation units that will remove fluoride contamination completely. A reputed non-government Research and Training Institute in Mandvi, Gujarat is one such organisation. Simply constructed and requiring only the heat of the sun these units are ideal and easily maintained in rural villages.

Membrane Techniques

Membrane techniques comprise technologies such as reverse osmosis, nanofiltration. dialysis and electro-dialysis. These systems use advanced technology and have relatively high capital cost and running costs but can discharge large quantities of highly treated water. Some actually require minerals to be put back into the treated water to give it a more normal drinking water quality. Invariably these systems require special companies to install them and are only successful when fully maintained by the provider and paid for on a volume basis. Communities cannot be expected to maintain them. A drawback to membrane systems is the discharge of waste from the treatment process that is highly toxic and requires special disposal methods.

Package household treatment units

In India there has been a massive increase in the availability of package household treatment units that remove most contaminants, including bacteriological ones. These units are currently not affordable for average rural families and largely inappropriate as they require an adequately pressurised water supply and available electricity. They are only applicable in the more affluent urban households but are selling in ever increasing numbers. They are also more appropriate for hospitals and health centres where a local maintenance service can be provided by the supplier.

Rural Filter

Researchers at Tata Consultancy Services Innovation Labs are developing water purification technologies appropriate for India. The team believes the most appropriate technologies for water treatment in India are those which do not require electricity or regular user intervention.

The key ingredient of the TCSIL filter is a matrix of pebbles, cement, and rice husk ash, a by-product of the paddy industry which, while had little or no value to the rice growers, was a highly effective filtration medium.

The fluoride removal solution incorporates a novel coating on rice husk ash to generate a high capacity adsorption medium which is selective to fluoride at specific acidic values. The system also incorporates a pre-defluoridation step to further increase the capacity of adsorption media while simultaneously controlling the alkalinity of the water. Water first enters the pre-defluoridation section wherein a small amount of coagulant is added to it by a solid candle. The coagulant forms a floc which attracts the fluoride ions from the water and gets captured in a floc collector at the bottom of the unit. Water subsequently flows upward through the adsorption media which removes the remaining fluoride ions and fluoride-free water flows out of the outlet of the unit. Each unit is capable of treating 500 litres of water.

The fluoride filters are currently undergoing extensive in-lab testing. Multiple 500 liter capacity fluoride removal units were tested against challenging levels of 10 parts per million of fluoride. The fluoride removal unit is capable of reducing the levels of fluoride ions present in the input water to below the WHO and Indian standard limit of 1.5 parts per million over its prescribed life.

Iron

Rice husk ash (RHA) filtration

Rice husk ash obtained from a rice husk stove can be used for treatment of contaminated water. It has been reported that absorption efficiency of RHA is 60%, 30% and 78% for iron, fluoride and microbial contamination, respectively.

Manganese dioxide sand filter

Ungraded sand coated with manganese dioxide was found to be a successful, simple and cost effective way of removing iron from drinking water in a domestic unit. The filter can be easily set up and a suitable flow control used. Regeneration of the media is by potassium permanganate, which is readily available.

Magnesium Peroxide

Magnesium peroxide in composition with immobilised copper and silver nano particles has been developed for purification of drinking water. The product has been tested to inactivate pathogenic micro-organisms like coliform, salmonella and shigella and for the removal of iron and arsenic from drinking water.

SEUF Household sand filter

A household and community level iron removal filter has been developed by Socio Economic Unit Foundation and introduced in South India in rural households. The filter uses a 2cm bed of charcoal above a 40 cm thick layer of river sand on a gravel bed with an aeration mechanism at the top. It was found that village women were able to maintain the filters after short training. The filter needs cleaning after 3-4 weeks when treating 10 mg/l of iron. The cost of this IRP is Rs 2500.

NEERI HP linked IRP

NEERI has developed and field tested in Assam an iron removal plant for handpumps and piped water systems. These plants can remove iron from 50mg/l to below 0.3 mg/l. The construction is based on a cylindrical tank system of 1 m3/hour capacity using hume pipes or on-site rcc/ferro-cement. The major components are aeration chamber, sedimentation tank and filter. Maintenance involves simply removing the top 5 cm of sand from the filter, washing it and replacing. Cleaning is required every month for contamination above 5 mg/l and every two months with a lower figure. A 250 person plant costs about Rs 50000 (2011 prices). Other similar plants have been developed by Central Mechanical Engineering Research Institute, Durgapur, DRDO and Balaji Industrial and Agricultural Castings.

CSIR-CGCRI Ion Specific Resin Unit

Central Glass and Ceramic Research Institute has developed an ion specific resin unit for removal of arsenic and iron from drinking water. This is achieved by coagulation and precipitation. It is easy to install and operate. The cost of the filter is Rs 4000 for 25 litres per hour capacity domestic unit.

CSIR-NEERI Household Iron removal filter

This household filter unit works on the principle of oxidation of iron by potassium permanganate and removal of precipitated iron by sand filtration. The dose of potassium permanganate is added to the raw water and mixed for 5-10 minutes manually. The mixture is then passed by gravity through the sand filter and treated water with under o.2 mg/l iron is collected in a storage container.

Terafil Water Filter

This low cost iron removal filter has been developed in Odisha by IMMT. The filter consists of a Terafil disc (available from IMMT or made in a village location under guidance) that is porous sintered red clay (clay, river sand and sawdust mix that is fired in a small kiln) that filters out iron, sediments, suspended particles, and certain micro-organisms. About 99% of turbidity, 95-100% of micro-organisms, 90-95% of soluble iron, colour and odour are removed. A household version with 1-4 litre per hour is available as is a community version that can be greatly increased in throughput by addition of on-line pressure.

Nitrate

Nitrate is a stable and highly soluble ion with low potential for co-precipitation or adsorption. This means nitrate is difficult to remove using simple household based units with coagulation and filtration. Treatment of nitrate contamination is expensive and complicated, relying on Adsorption or Ion Exchange, Biological Denitrification, Catalytic Reduction, Reverse Osmosis or Electrodialysis.

It is therefore necessary to look at alternative approaches to minimise the risk to health.

Blending

A solution to high nitrate levels in a particular source of drinking water, where other, less contaminated sources are nearby, is blending. The blending proportion depends on the level of contamination and a safer response in this situation is to ensure the contaminated source is used for non-consumptive use and drinking water is consumed only from a less contaminated one. This requires the community to be aware and careful water quality monitoring to be regularly carried out.

Protection of infants

The highest risk from nitrate poisoning occurs with infants under 6 months of age. It is therefore imperative that all infants in the locality of a too contaminated source are breast fed milk up to at least the age of 6 months and not fed drinking water contaminated by high nitrates.

Ion Exchange technology

Ion Exchange India Limited has developed, installed and operated nitrate removal technology including for both handpumps and community systems. It is clear, however, that to maintain reliability it is necessary to have a long term maintenance agreement with the supplier and installer based on provision of a certain quantity of treated water for an agreed price.

Salinity

Solar Stills

Natural sunlight is used to evaporate pure water from high TDS water in a solar still. The condensing water is deposited on a glass surface above the contaminated water that runs down to a collection channel and into a storage point. This system requires no energy but will need a large land area for large volumes. It is an appropriate household system. 1 m^2 of collection area should produce between 3 and 6 litres per day. Even sea water can be treated in this way.

The Energy Research Institute (TERI) is developing a much higher output solar desalination unit with a target of 100 litres per day from 10 flat plate collectors that will have a much lower cost per litre than a small conventional solar still.

Rooftop rainwater harvesting

In a situation where there is a complete lack of good quality water, whatever measures are instituted to solve the problem should be augmented by rooftop rainwater harvesting. This ensures collection of good quality water during monsoon rains for storage and use by the collecting household. Ferro-cement tanks are adequate for storage and, with proper training; villagers can construct these themselves, thereby reducing the capital cost.

Reverse Osmosis

Reverse Osmosis (RO) is one of the fastest growing techniques for desalination of contaminated water that has a high TDS. In RO the feed water is pumped at high pressure through permeable membranes, separating the salts from pure water. Depending on the feed water quality a range of ancillary treatments may have to be employed for removing sediments, correcting pH, removing excess chlorine, etc. This system will only be successful if a long term maintenance contract is established with a reliable organisation and responsibility is kept with an active and dedicated Panchayati Raj organisation. Small household RO units are becoming very popular in India in urban cities but it will be some time before they will sustain in the rural setting.

Other types of treatment for high TDS water are available but they tend to be more complex and expensive than equivalent size RO systems and are not therefore considered appropriate in a rural setting.

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