NEW HOPE FOR HUNDRED OF MILLIONS SUFFERING FROM POISONED WELL WATER

When rivers run dry

Rivers and lakes are polluted and an increasing number of people have to rely on well-water for drinking.

Some of the new wells contain Arsenic, Fluoride, Uranium, Radon, Aluminum, Copper, Cadmium, Barium, Lead, Manganese and other minerals in concentrations that are poisonous in the long run. These minerals that have been there before, but the water has not been used for drinking before.

More than one billion people now drink water that is more or less poisoned by natural minerals.

Scarab Development AB has devised inexpensive, absolutely reliable and robust equipment that will remove all contaminants from water.

Just starting to drink pure water will restore the health of millions.

In 2017 one system will be installed in Bangladesh and another in India.

One billion people drink unhealthy water today

According to latest reports up to 500 million people worldwide suffer from arsenic or fluoride poisoning. At least as many are slowly being poisoned by well water containing too high levels of other unhealthy natural minerals.

This is a calamity that started about 50 years ago and is rapidly increasing.

The main reason for this epidemic is that pollution of rivers and lakes motivate more and more people to rely on digging or boring for groundwater. Some of these groundwaters contain and have always contained unhealthy levels of Arsenic, Fluoride, Uranium, Radon, Aluminum, Copper, Cadmium, Barium, Lead, Manganese and other minerals.

In Bangladesh international aid agencies bored wells to help the people avoid contaminated surface water. Millions of wells were bored to produce clear groundwater. Only later it was found out that at least half of these wells contained high levels of natural arsenic with severe health consequences.

In the state of Odisha in India there was also Arsenic in the well water, so one had to sink a deeper well, only to find that it contained dangerous levels of Fluoride.

With financial support from the Swedish International Agency for Co-operation (Sida), the Royal Institute of Technology in Stockholm, Sweden (KTH) has made a feasibility study regarding a new method to remove arsenic and fluoride, uranium and other contaminants in an extremely efficient way.

The study concluded that all contaminants were removed completely and that the system is easy to run and economically feasible.

The technology has been licensed to HVR Water Purification AB. HVR will start its activities in 2017 by installing one microgrid system in Bangladesh and another in Odisha, India.

PROJECT TEAM

During the more than a decade that the development of a sustainable solution for providing pure drinking water to people with poison wells and other water problems has been running, a large number of engineers, students and scientists have been involved. Masters an d Doctoral studies have been completed. Experimnental models and prototypes have been built. Feasibility studies have been performed. In the final commercial step some of these people are still involved but the main work will be done by the following project team.

From left to right:

Andrew Bates, KTH, student of solar power, will advise on solar power integration

Urban Rydholm, Professor emeritus, Indo-Swedish Rheumatology Foundation Trust, will be responsible for setting up a supply of pure water to 200 children in a school next to his hospital

Daniel Woldemarian, Doctoral student, Topic: Polygeneration, will plan for a demonstration unit in Ethiopia

Ershad Khan, Doctoral student, Topic: polygeneration of electricity and arsenic free water, will be responsible for energy calculations

Henrik Dolfe, engineer, Xzero AB, will oversee delivery and installation in Bangladesh and India.

Jan Kramle, project manager in Bangladesh

Aapo Sääsk, VD HVR Water Purification AB, will deliver the equipment

RECENT RESEARCH

Fate of over 480 million inhabitants living in arsenic and fluoride endemic Indian districts: Magnitude, health, socio-economic effects and mitigation approaches,

Journal of Trace Elements in Medicine and Biology, Dipankar Chakraborti, Mohammad Mahmudur Rahman, Amit Chatterjee, Dipankar Das, Bhaskar Das, Biswajit Nayak, Arup Pal, Uttam Kumar Chowdhury, Sad Ahmed, Bhajan Kumar Biswas, Mrinal Kumar Sengupta, Dilip Lodh, Gautam Samanta, Sanjana Chakraborty, M.M. Roy, Rathindra Nath Dutta, Khitish Chandra Saha, Subhas Chandra Mukherjee, Shyamapada Pati, Probir Bijoy Kar, Available online 11 May 2016

Abstract

During our last 27 years of field survey in India, we have studied the magnitude of groundwater arsenic and fluoride contamination and its resulting health effects from numerous states. India is the worst groundwater fluoride and arsenic affected country in the world. ... Out of a total 29 states in India, groundwater of 20 states is fluoride affected. Total population of fluoride endemic 201 districts of India is 411 million (40% of Indian population) and more than 66 million people are estimated to be suffering from fluorosis including 6 million children below 14 years of age. Fluoride may cause a crippling disease. In 6 states of the Ganga-Brahmaputra Plain (GB-Plain), 70.4 million people are potentially at risk from groundwater arsenic toxicity. Three additional states in the non GB-Plain are mildly arsenic affected. For arsenic with substantial cumulative exposure can aggravate the risk of cancers along with various other diseases. Clinical effects of fluoride includes abnormal tooth enamel in children; adults had joint pain and deformity of the limbs, spine etc. The affected population chronically exposed to arsenic and fluoride from groundwater is in danger and there is no available medicine for those suffering from the toxicity...

Fluoride and Arsenic in Groundwater: Occurrence and Geochemical Processes Controlling Mobilisation,

K. Jha , V.K. Mishra, 11 August 2016, in *Innovative Saline Agriculture,* pp 351-369

Abstract

Fluorine and arsenic are the two toxic elements whose contamination in groundwater has posed toxicological problems across the globe. The fluorine contamination in the groundwater has been reported in about 25 countries in the world, whereas arsenic is present in the groundwater of nearly 70 countries, affecting millions of people from the dreaded diseases “fluorosis and arsenicosis”, respectively. The fluoride and arsenic contamination in the groundwater is basically a natural phenomenon influenced by local and regional geological settings as well as hydro-geochemical conditions. The weathering of rocks, leaching and percolation from the minerals may be the prime reason for such contamination…

FLUORIDE IN PRIVATE WELLS MAY CAUSE AN IQ DECLINE

"…In small quantities fluoride is known for helping to tamp down the blight of tooth decay; most municipalities in the U.S. add it to their water supplies as a public health measure …"

"But at higher levels, fluoride can lead to pitted teeth and discoloration. It also makes bones brittle and more prone to fractures. And recent studies have also linked high levels of fluoride exposure with IQ deficits …" *Excerpt from Scientific American, Aug 20, 2014*

Fluoride is Killing Your Brain

A landmark study by Dr. Phyllis Mullenix in 1995 showed that fluoride crosses the blood-brain barrier, a shield that prevents certain substances from reaching the brain and spinal cord. Translation: Fluoride gets direct access to your neurons in a way many common toxins, viruses and microscopic bacterial infections cannot.

And what's more, fluoride helps another dangerous substance get inside the brain: aluminum. Aluminum is a neurotoxin known to contribute to neurological disorders and diseases. And fluoride assists the toxic element: A 1998 study in Brain Research, a peer-reviewed medical journal, showed that the presence of fluoride in rats significantly increased the rate at which aluminum crosses the blood-brain barrier and accumulates in the brain.

That's why fluoride can lower your IQ, and scientists have noticed fluoride causes brain deterioration similar to that of Alzheimer's disease and others types of dementia. Not surprisingly, there is an eye-opening correlation between the surge in the rates of Alzheimer's and the time since fluoridation became an official policy of the U.S. Public Health Service in 1951.

Fluoride joins lead, arsenic, mercury, toluene and other chemicals known to harm the brain. Other scientific studies on fluoride show a correlation with bone, respiratory and oral cancers. It also contributes to thyroid damage, bone fragility in adults, and immune system disruption. *John Ross Crooks*, SOVEREIGN LIVING | 09.13.2014

FLUORIDE IN DEEP WELLS

One of the main suggestions for remediating Arsenic contamination that has been proposed is to sink deep bore wells into strata that do not contain arsenic. Deep wells are of course more expensive, but there are also some problems that may occur. One is that arsenic may migrate to these strata from higher strata once the water is being drawn.

Another is that these strata may already contain other contaminants. One example is the hospital in Odisha where an arsenic containing well was replaced by a deeper well which turned out to contain fluoride.

This problem has now been documented in a scientific report about ground water systems in the Haldiati-Doboka Areas, Assam, which says that “The deep tube well samples contain comparatively more fluoride content than the hand tube wells and surface water source is comparatively free (from fluoride). The fluoride content as evidenced from the study is increasing with the increase in deepness of the bore well. *International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, Volume 5 Issue 4, April 2016,* U. Tamuly, P. Kotoky, KG. Bhattacharyya, Department of Chemistry, Namrup College, Parbatpur - 786623, Dibrugarh, Assam, India.

RURAL POLYGENERATION MAY PROVIDE ELECTRICITY AND PURE WATER IN BANGLADESH

Bangladesh has been afflicted by the worst human poisoning in history (WHO). Tens of mil- lions of wells contain high levels of natural arsenic. The wells have been dug with international assistance during the last decades in order to use ground water as a source of drinking water instead of surface water. The wells were dug because the surface waters were severely poisoned by bacteria, algae and other microorganisms.

Since both detecting and removing arsenic are technically very complicated tasks, and because of the sheer magnitude of the problem, the Government of Bangladesh found it necessary to request assistance from the international community – ironically, often the same organizations that financed the wells.

As soon as the enormity of the plight was widely acknowledged, the World Bank, Unicef and several dozens of private and public aid organizations stepped in to help.

Today both the World Bank and Unicef, after having spent tens of millions of US$, have thrown in the towels and their final reports show that also many other of the still ongoing pro- jects will meet with large problems and probably fail.

The basic reason for the failure is lack of afterthought and analysis. Just as some decades ear- lier the common cry was: "Surface water is contaminated - let's dig wells!" (Once everyone was digging wells, it certainly seemed to be the right thing to do!) Now the cry was: "There is arsenic in the water - let's remove it!" And soon hundreds of companies and scientist were proposing technologies for removing arsenic. Many projects were started and they all ran into difficulties.

There were several reasons for the difficulties.

1. Arsenic has no colour and does not smell or taste. And there is no cheap detection method. Therefore, for any method proposed, the user must trust that the arsenic is really removed. For the methods that have been tested and proven to remove arsenic in Bangladesh there is unfortunately no way for the user to check how efficient it is, if it works to start with, if it continues to work, how long the active ingredients lasts etc. For that reason, the user may be reluctant to pay for and/or take the trouble to use the method.

2. Most of the people afflicted have limited cash income. That people with no cash income or limited cash income have difficulties in acquiring spare parts, service, fuel etc for equipment that they own is obvious. The methods that have been found to be efficient in removing arsenic usually have a fairly low capital cost and a comparatively higher running cost. Annual service and replacement may cost more than the initial equip-ment. So the cheap "five dollar solutions" sought after and often supported by the aid agencies have generally failed, if for no other, then this reason.

3. Some of the proposed methods have limited removal efficiency. They may be tested to remove a certain percentage of arsenic and thus reduce contamination to below permitted levels provided that the initial concentration is not too high. An equipment like this may appear "good enough" or "better than nothing" for the Government or aid organisation. However, not being entirely sure if the equipment is good enough is not encouraging for the user – and as we said in (1), there is no way of finding out how good it really is.

4. For a scientist, finding the perfect method for removing arsenic is a true accomplishment and several awards have been given for such accomplishments. However, for the user the question lingers, what else is there in the water. It is known from Gujarat that symptoms blamed on arsenic after systematic testing of the water were found out to be caused by high concentrations of fluoride instead. Luckily, the detailed testing was done before arsenic removal equipment was installed. Yet, even if tests verify arsenic, the user is likely to become more well-informed after the intervention. In the end the question will arise: what about fluoride, lead, cadmium, mercury, uranium, strontium....pesticides, insecticides and other chemicals!

5. Since many of the methods introduced in Bangladesh rely on manual handling of the equipment there is a danger that the well water that is initially free from microorganisms can be contaminated in handling. After an acute bout of intestinal infection, the user will be reluctant to continue using the equipment. For many users the choice is anyway between the immediate risk of intestinal infections which is the curse of sur- face water and the long term probable outcome of arsenic poisoning. The choice is not entirely obvious.

6. Another obvious complexity in the interventions has been the assumption that the objects of the interventions will be forever poor. The tendency has been to select methods that are as cheap as possible without contributing anything than just solving the problem as such. That is obviously a very inefficient use of resources. Sometimes acute interventions are needed, but charity without social development will just sustain poverty.

7. As in all aid interventions the arsenic mitigation programs have been plagued by the inequity syndrome. An international intervention cannot just fly in. To have a chance of efficiency in its initiation it needs local intelligence and to have a lasting impact it must support local capacity building. Although directed towards the poorest segments of the population it has become increasingly apparent that much of the resources are appropriated by international and local experts and bureaucrats. This is of course detrimental to the marginalized people and their chances for long term social improvement.

Some of the prerequisites for a sustainable solution would therefore be:

1. It must be evident for the users that the intervention removes arsenic.

2. Recurring costs must be small.

3. The intervention should remove all arsenic completely.

4. The intervention should not leave other potential contaminants untreated.

5. The technology used should not risk causing other contamination.

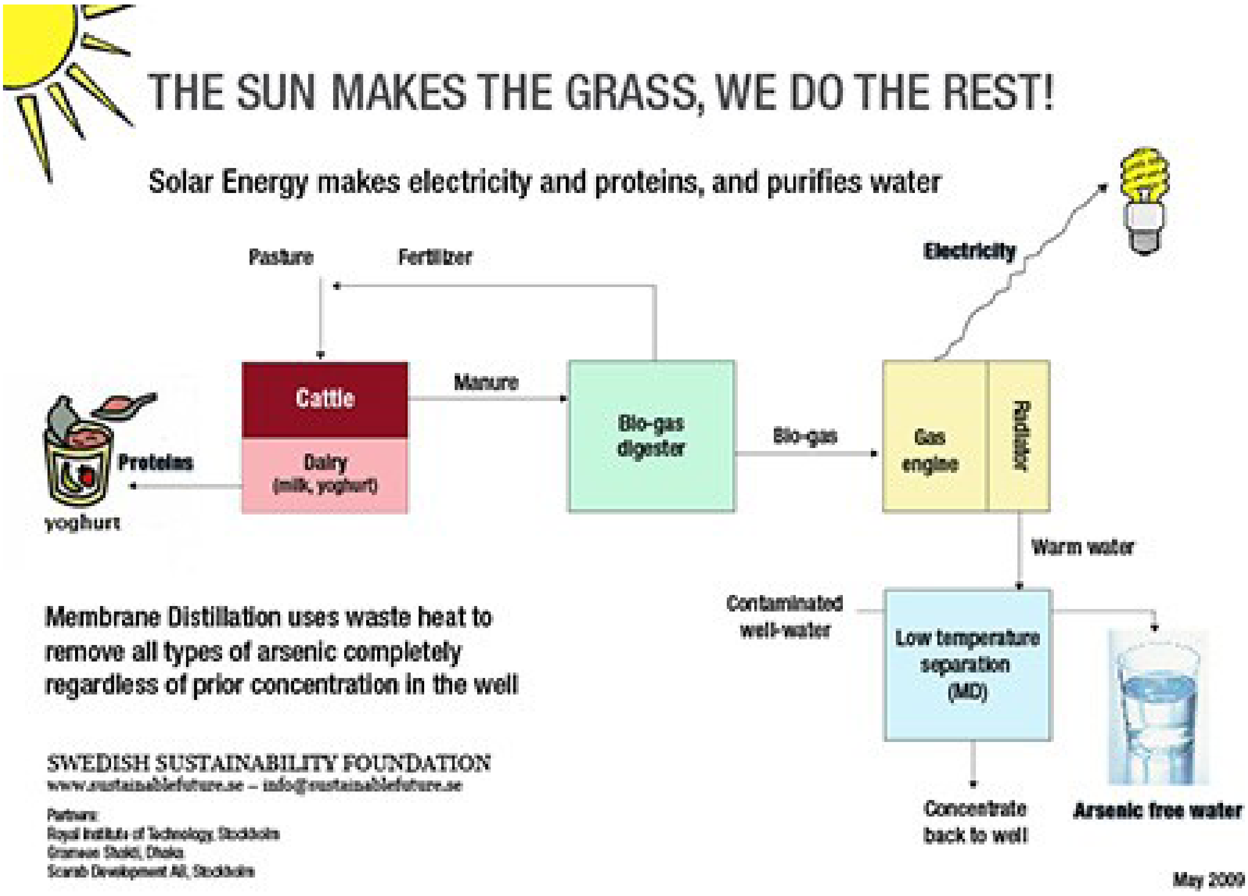
6. The intervention should not only be a cost but part of building a more prosperous society.

7. The intervention should not increase inequality.

SMALL-SCALE RENEWABLE POLYGENERATION IN BANGLADESH FOR ELECTRIC POWER GENERATION AND ARSENIC-FREE WATER PRODUCTION

The Royal Institute of Technology (KTH) and the Nobel Price winner Grameen co-operate in a project that uses waste heat from energy production to purify water. Electricity and clean water in rural areas would make it possible for rural people to make a living instead of moving to the slum of the cities on the hunt for a job.

ERSHAD ULLAH KHAN, M.Sc. Mechanical Engineering, is project manager at KTH.



Planning for membrane distillation for fluoride removal from a deep-bore well in a village in Odisha, India.

Background

Chronic poisoning caused by excessive intake of fluoride from drinking water for a long time is endemic in many regions in India and endemic skeletal fluorosis (ESF) affects above 100 millions of people in different regions in India.

Lack of surface water has resulted in groundwater from deep-bore wells being used as sources of drinking water in many areas. Over half of the groundwater sources in In- dia have fluoride above recommended levels.

Clean commercial drinking water is not available to people living neither in town nor in small villages in the countryside.

Fluorosis

The WHO guideline value of limit for fluoride in drinking water is 1.5 mg/L. Studies in India and China have however repeatedly documented skeletal fluorosis also at levels as low as 0.7 – 1.5 mg/L.

Teeth (dental fluorosis)

Figure 1.
Discoloration of teeth in a 10-yrs old boy

White, chalky opacities or patches on tooth enamel is the first sign of fluorosis in children. It is followed by distinct brownish discoloration of the teeth (Figure 1) and finally by pigmentation and pitting of the enamel surfaces, sometimes with chipping of edges.

Non-skeletal affection

Common clinical symptoms of fluorosis are digestive tract symptoms like pain in abdomen, diarrhea, constipation and neurological symptoms like tingling and numbness, increased tendency to urinate and increased thirst. Muscle pain, stiffness and weakness may also be present. These symptoms may appear before the onset of skeletal fluorosis and may therefore be useful in early diagnosis.

Skeletal fluorosis

Increased metabolic turnover of the bone, impaired bone collagen synthesis and increased avidity for calcium are features in fluoride toxicity. Thickening of the bone structure and accumulation of bone tis- sue both contribute to impaired joint mobility. Ligaments and cartilage can also become ossified resulting in immobilization of joints of the axial skeleton and of the major joints of the extremities (Figure 2).

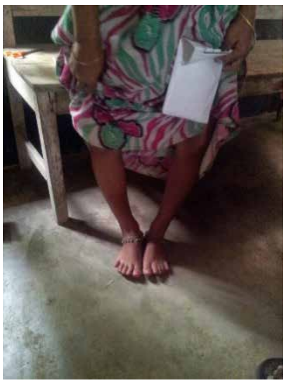
Figure 2.
Maximal flexion of the elbows in a 40-yrs old man

Figure 3.
Final stage of skeletal fluorosis. Middle-aged man totally unable to move and asking for help to die

Figure 4.

A combination of osteosclerosis, osteomalacia and osteoporosis of varying degrees as well as exostosis formation characterizes the bone lesions (Figure 3).

The final stage implies general stiffness (white color on the X-ray) with immobility and severe disability (Figure 4).



Growth disturbances due to softening of bone are common in children and irreversible without surgery (Figure 5).

It is important to remember that early stages of skeletal fluorosis are not clinically obvious, and may be misdiagnosed as rheumatoid arthritis or other inflammatory joint diseases!

Figure 5.
14 year old girl gravely bow-legged on account of secondary fluorosis

Treatment

Nutritional supplements containing vitamins C, D, antioxidants, and calcium are advised to re- duce the deleterious effects of excessive fluoride. Providing defluoridated water is however the only way by which the generation yet to be born can be totally protected against the disease.

With removal of fluoride exposure, skeletal fluorosis is reversible, but likely needs decades. Un- fortunately, for most of those already afflicted, complete reversal of pathological changes and clinical manifestations will not be possible; in these cases, we may at best hope that the disease does not get worse.

If fluoride intake is stopped, the fluoride existing in bone structures will deplete and be excreted via urine. However, it is a very slow process to eliminate the fluoride from the body completely. Minimal results are seen in patients who will excrete large amounts of flouride for years.

Shakuntala Hospital in Balasore, Odisha

Shakuntala Hospital was inaugurated in 2013 and made possible by contributions to the In- do-Swedish Rheumatology Foundation. Patients with disability due to joint pain from inflammatory diseases are treated in an outpatient clinic at the hospital by Scandinavian and Indian rheumatologists as well as orthopaedic surgeons. Besides rheumatological diseases a number of patients show up with atypical rheumatoid arthritis or osteoarthritis at low age. Our attention has thus slowly moved to prevention of joint pain and immobility possibly due to skeletal fluorosis.

Repeated visits to a village close to the hospital have revealed high fluoride content in the drinking water from a deep-bore well serving about 200 school children, almost all of them showing dental fluorosis. Quite a number of adult inhabitants have shown all stages of skeletal fluorosis, fifteen adults having died from fluorosis in the ages of 20–35 years during the last three years.

We are now planning to primarily offer the school children clean drinking water by installation of a new microgrid.

The effects of clean drinking water can be registered by obtaining blood and urinary samples for fluoride analysis. That is however practically impossible with regard to the costs and limited possibilities of collection and transportation of both samples and patients. Furthermore information on the skeletal findings is of more informative value than the fluoride content of blood and urine. This can be achieved by DEXA (dual energy X-ray absorbiometry) measuring of bone mineral density. Contributions to our foundation making it possible to invest in such an apparatus is a dream that will hopefully come true.

Summary

Access to clean drinking water is still a challenge in many parts of India. Even if inhaling fluoride dust or gas from industries is as harmful to health as ingesting fluoride-containing water or food. Our contribution has for now to be limited to cleaning of drinking water for children, hopefully reducing the harmful health effects of fluoride intoxication and premature death.

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INDO-SWEDISH RHEUMATOLOGY FOUNDATION IN ODISHA, INDIA.

Over half of groundwater sources in India have fluoride above recommended levels. Endemic skeletal fluorosis is widely prevalent and is a major public health problem.

The most common cause of fluorosis is fluoride-laden drinking water which is sourced as groundwater from deep-bore wells. As the water run dry in ground wells decades ago, people were forced to dig deeper to reach water. At those depths they got sufficient amounts of water, but also high levels of fluoride contamination.

A person's diet, general state of health as well as the body's ability to dispose of fluoride all affect how the exposure manifests itself. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems. The bone is hardened and thus less elastic. Thickening of the bone structure and accumulation of bone tissue in ligaments and cartilage contribute to impaired joint mobility, impairment of muscles and pain. Chronic intoxication may cause untimely death.

ISRFT (Indo-Swedish Rheumatology Foundation Thrust) operates a charity hospital in the town of Balasore in Odisha (www.shakuntalahospital.com). Besides patients with inflammatory joint diseases a number of young people with severe osteoarthritis are seen in the outpatient clinic. It may be that this is an effect of skeletal fluorosis. Increased stiffness of subchondral bone most probably increase the risk of premature osteoarthritis with accompanying health care burden.

In a village close to Balasore the whole population show severe signs of fluorosis, i.e. growth disturbances and discolored teeth in children, joint contractures, pain and premature death in adults. One well serves the school as well as many inhabitants. Water purification at the well could thus be helpful for a large number of people, and especially save school children from intoxication.

Removal of excessive fluoride from drinking-water has been difficult and expensive, but new technology is promising. Fluorosis is reversible depending on the progression of the disease. If fluoride intake is stopped, the fluoride existing in bone structures will deplete and be excreted via urine. However, it is a very slow process to eliminate the fluoride from the body completely.

ISRFT needs help to purify the drinking water in the above-mentioned village and plan to study the effects of that by analysis of fluoride content in blood and urine as well as perform clinical follow-up.

FLUORIDE CONTAMINATED DRINKING WATER IN ETHIOPIA

Distribution, present practices of dealing with the challenge and future solutions

Access to clean drinking water is still a challenge in many parts of Ethiopia. Even though Ethiopia is referred as water tower of Africa, people living in large part of the country suffer from lack of clean water for human and animal drinking. Especially the eastern part of Ethiopia struggles with shortage of surface water. Boreholes are widely used as sources of water in those areas where springs, rivers and lakes are not abundant unlike the rest of the country. In many of such contaminated drinking water sources, chlorination would make the water safe to drinking.

The borehole water in the areas inside the Ethiopian Rift Valley consists of high level of fluoride which requires removal. The drinking water for the people in those areas has reportedly high level of fluoride. Fluoride reaches the water supply from the geological rock formations of the Ethiopian Rift Valley. Studies have recorded levels of fluoride as high as 25 milligrams per litre in those areas. These excess levels of fluoride are affecting more than 14 million women and children from Afar, Oromia and the Southern Nations Nationalities and Peoples Region (SNNPR), as well as parts of the Ethiopian Somali Region(Johnson et al., 2011; "UNICEF Eastern and Southern Africa - Media Centre - Ethiopia, 18 May 2015: Drilling Deep to Keep Children's Teeth and Bones Protected," n.d.).

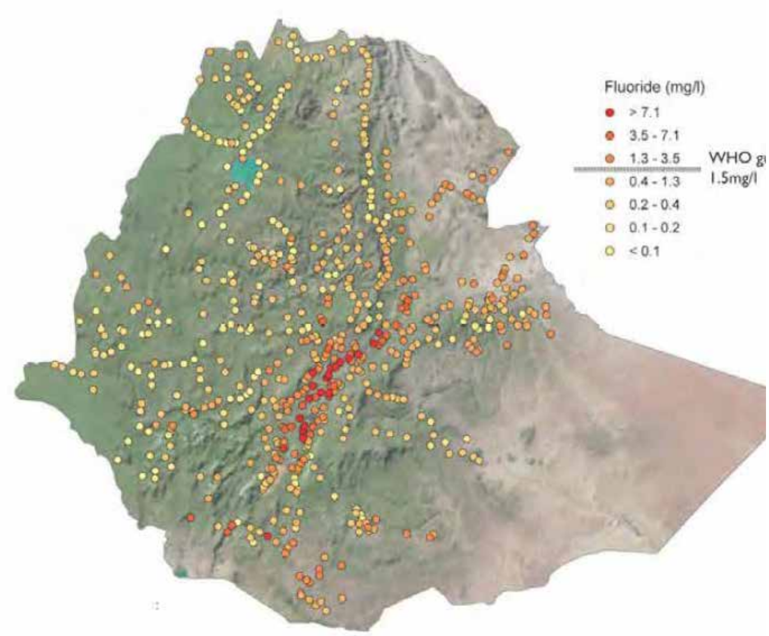

Figure 2. Occurrence of fluoride in groundwater in different parts of Ethiopia(Ministry of water resource (FDRE), 2011)

Related health problems are widely observed on inhabitants from this area (R Tekle-Haimanot, Fekadu, Bushera, & Mekonnen, 1987; van Steenbergen, Haimanot, & Sidelil, 2011) such as dental and skeletal fluorosis. A study (Redda Tekle-Haimanot & Haile, 2014) has also reported very high prevalence of skeletal fluorosis in local alcoholic beverage consumers. Other health problems observed on consumers of fluoride contaminated drinks include stiffness, Rheumatic pain, limitation of mobility, squatting difficulty, and walking difficulty (Redda Tekle-Haimanot & Haile, 2014).

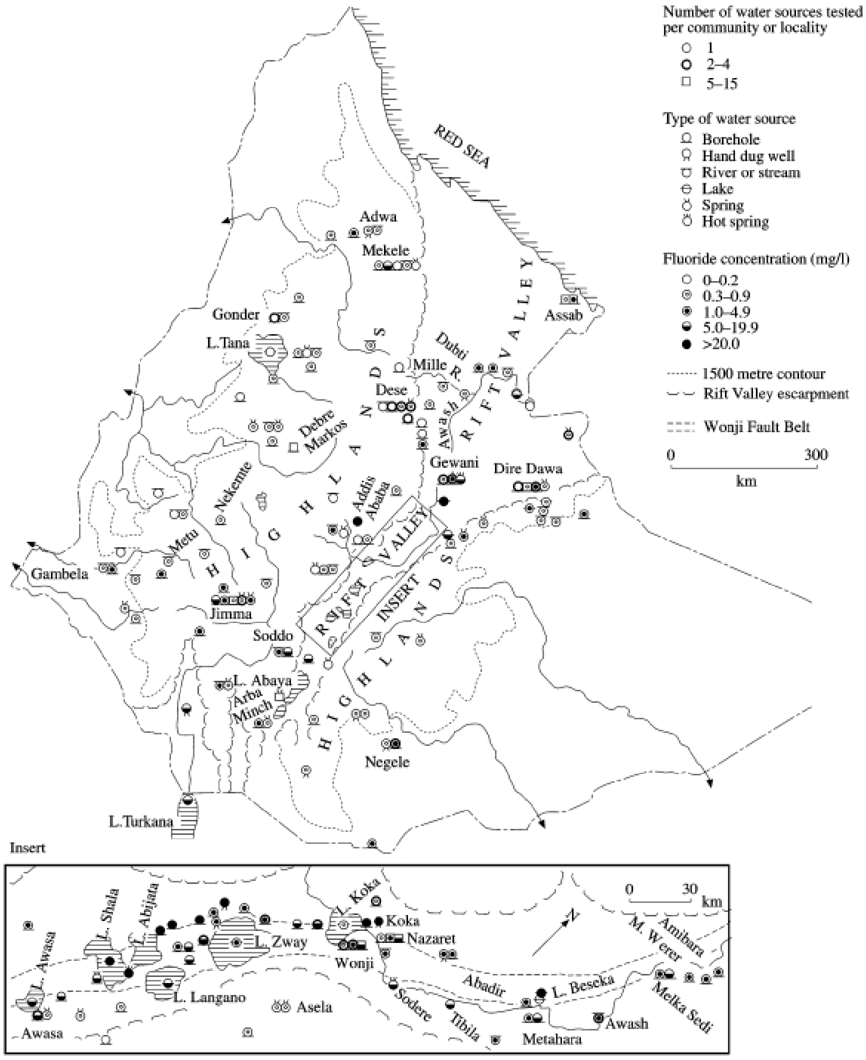

Figure 2. Fluoride concentration in 270 water sources, by type of source (Kloos & Tekle Haimanot, 1999)

Removal techniques practiced and studied

Fluoride removing units based on pellet and bone char (Esayas, Mattle, & Feyisa, 2009; John- son et al., 2011) have been started in few areas with the help of NGOs (Osterwalder et al., 2011). The removal is based on filtering the contaminated water by adsorbing the fluoride on the pellets and bone char active surfaces and replacing the adsorbent regularly as shown in Figure 3. The predicted cost for this process is between 3 and 4.5 USD/m3.

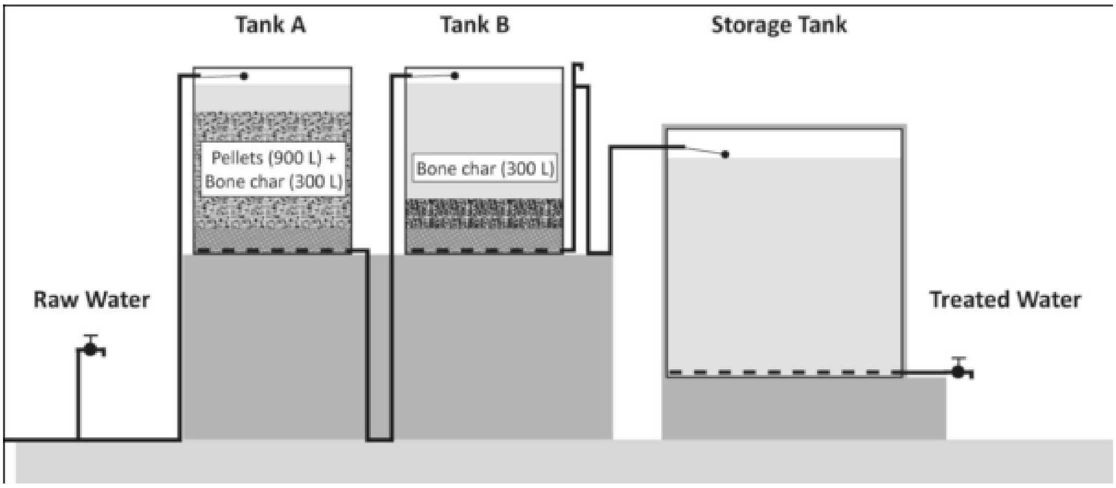

Figure 3. Design of the fluoride removal community filter in Ethiopia (Osterwalder et al., 2011)

Membrane distillation for fluoride removal

Membrane distillation (MD) based on direct contact configuration has been tested and showed to be effective in removing fluoride even at high feed levels (500 mg/L) (Hou et al., 2010). In another study (Boubakri, Bouchrit, Hafiane, & Al-Tahar Bouguecha, 2014) fluoride rejection of up to 99.9% was reported using DCMD process. A sample of salt water contaminated with arsenic and uranium in addition to fluoride, was tested for purification by using DCMD using different membrane materials of various pore sizes (Yarlagadda, Gude, Camacho, Pinappu, & Deng, 2011). Effective removal efficiencies of up to 99.95% were reported.

Characteristics of membrane distillation

Since the MD-process itself takes place at temperatures below 100 °C and at ambient pressure, requirements to withstand high temperatures and/or pressures are eliminated. Membrane and module costs are important for the capital costs of equipment. For the same reason, operation and maintenance of the equipment is limited as long as costs for heating and cooling are low.

Further characteristics are:

- 100 % (theoretical) rejection of ions, macromolecules, colloids, bacteria, virus and other non-volatiles
- Lower operating temperatures than conventional distillation
- Lower operating pressure than membrane separation processes
- Low sensitivity to variations in process variables (e.g. pH and salts)
- Good to excellent mechanical properties and chemical resistance
- Reduced use of chemicals, filters and other consumables
- Self-regulating process
- Waste heat sources with temperatures below 100 °C can be used as the driving force in the process

The membrane distillation process can be powered by heat from solar thermal system dedicated for this purpose (as shown in Figure 4) or waste heat from power generating engine.

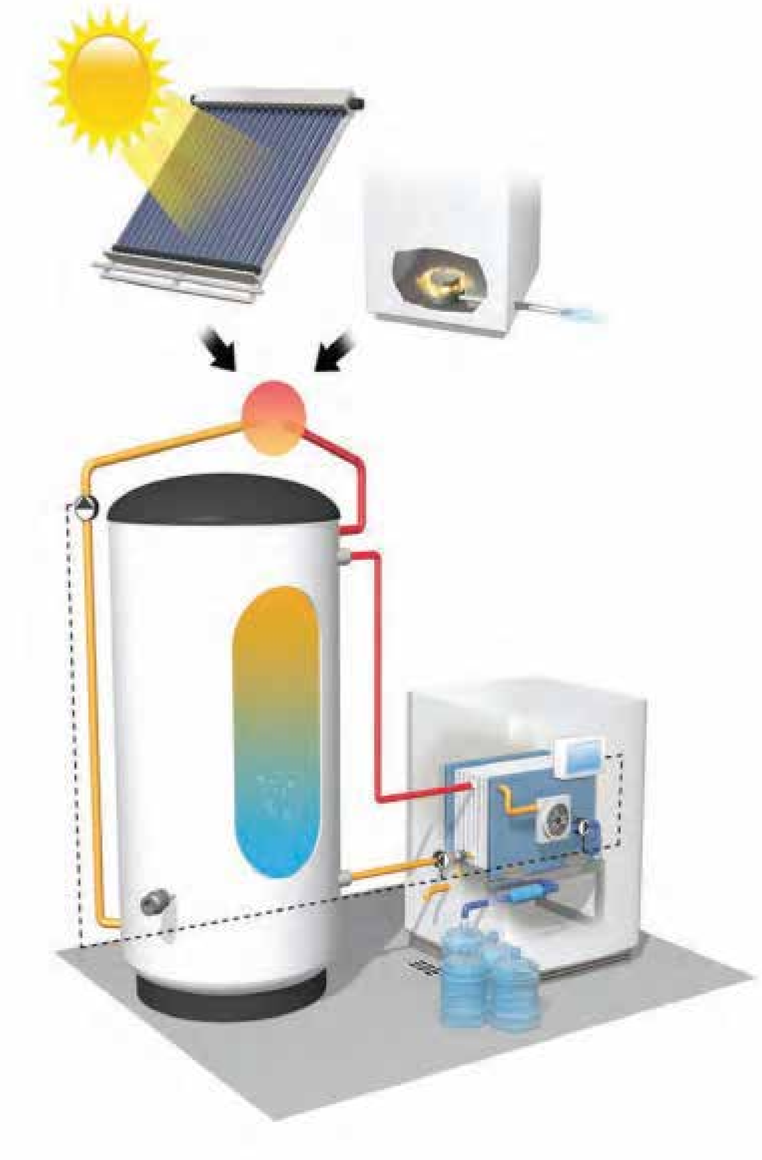

Figure 4. Membrane distillation (Elixir500) unit developed by HVR (HVR, 2016)

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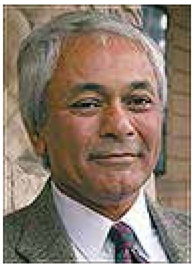

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