TURNING RAINWATER INTO DRINKING WATER: ADAPTING CONVENTIONAL MULTI-STAGE WATER PURIFICATION TECHNOLOGY TO PURIFY RAIN

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Abstract:

The water scarcity facing the world today in terms of both, quantity and quality, is serious. Several international efforts like the Millennium Development Goals of the United Nations and the declaration of the World Summit on Sustainable Development, are directed towards addressing the issue of lack of access to safe drinking water. Both aim to halve the number of two billion people who do not have access to safe drinking water by 2015.

One basic source of water that can achieve this goal is through harvesting the rain for drinking purposes. Rainwater harvesting is being successfully practiced in several developing and developed countries. However, this rainwater is usually used for non-potable purposes or for recharging depleting groundwater resources, not so much for potable purposes.

One of the main objections to the use of rain for drinking is that it is considered impure and polluted. While this may be true, it is ironic that secondary sources of water like rivers, lakes and groundwater, which are perhaps more polluted, are treated by applying state-of-the-art multi-stage water treatment technologies. Yet, we hesitate to apply the same to the rain. Moreover, our current strategies to deal with groundwater problems of fluoride and arsenic problems is by using filters that remove these dangerous elements. These filters however come with their own set of risks. In such cases, the use of alternate source of water – rain – makes more sense.

There is a need for a paradigm shift in the way we use rain. There is enough rain to meet at least drinking water needs and it must be used for drinking. Rainwatr use for drinking purposes will promote the use of a decentralised and low cost source of water, under user control. It will go a long way in meeting the Millennium Development Goals and achieving household and community level clean drinking water, in a sustainable manner. If impure, the rain can be treated by applying appropriate technology.

The present paper informs about rainwater quality and how rain can be purified to meet WHO drinking water guidelines using an innovative multi-stage water purification technology. It also describes the results of this technology on artificially created contaminated water.

Main paper

Case Study I: Bangladesh

Groundwater in villages in Charghat district of Bangladesh has beyond permissible levels of arsenic. Rather than use filters that remove the arsenic, the villagers are using another source – rain. The rain that falls on the roofs of the dwellings in the village is collected in earthen pots and used by the villagers. In 15 villages in Rajshahi district where arsenic is present in groundwater, some 140 drinking rainwater harvesting systems have been installed. According to the NGO Forum for Drinking Water and Sanitation, Bangladesh, an organisation involved in the project, the quality of water is potable if all necessary precautions are taken. The executive director of the arsenic cell of the Forum, S M A Rashid, an epidemiologist, feels that though low levels of *E coli* (S M A Rashid 2003, *personal communication*) are occasionally found in the stored rainwater, this problem is easier to deal with as compared to arsenic. Purifiying rainwater could be a solution for this.

Case Study II: India

In Kamarpara village in Malda district of West Bengal, there are no males who survive beyond thirties: the older men have been lost to arsenic present in the groundwater that they consumed.

Kamla Mondal is a 35 year-old women from Kamdev Kathi village, in North 24 Parganas District of West Bengal, India. Tubewells in this village contain arsenic beyond permissible levels. She is suffering from skin lesions; her hands have turned hard with blisters. She is no longer able to work as her energy level has declined. The doctors say that this is because she is drinking water containing arsenic. In spite of knowing the cause of her illness, because she has no other source of water, Kamla Devi continues to drink water from a tubewell, which has been marked red, indicating that the water contains above permissible level of arsenic. Meanwhile her health continues to deteriorate.

Case study III

In Bandana, a village in Dausa, a poor district of Rajasthan, India, several villagers can be recognised by their deformed bones. The reason for the deformity is excess fluoride in groundwater, their only source of water. Efforts are on by the Centre for Science and Environment, a leading New Delhi-based non-governmental organisation to promote rooftop rainwater harvesting systems so that the people can at least get fluoride-free water. Though this rainwater may not be sufficient to meet the year's potable water demands, at least this will help reduce the intake of water rich in fluoride.

Introduction

Several parts of the world today are experiencing a serious water problem, in terms of scarcity and quality. Several international efforts like the Millennium Development Goals, a set of ambitious goal set by the United Nations, are directed towards halving the number of people who do not have access to safe drinking water by 2015. The United Nations Environment Programme chose the theme *Water: Two billion people are dying for it'* for this year's World Environment Day which fell on June 5.

In India, the water problem is particularly serious. Secondary sources of water like rivers, lakes and groundwater have been hopelessly exploited. Most rivers that pass through towns and cities are no more than drains. These rivers hardly have any flow left, and serve as disposal sites for the city's industrial and municipal waste. Almost all over the country, groundwater levels are depleting at an alarming rate, with more and more zones being described as 'grey' or 'dark' implying little or no water left in the aquifer.

No sooner than winter is over and the temperature rises, reports start filling up national and regional dailies about water problems being faced by communities from towns and cities across the country (*Table 1: Water supply frequency*).

Table 1: Water supply frequency

Frequency of water supply in Gujarat

City	Frequency of municipal water supply
Surendranagar	Once in a week
Wadhwan	Once in 5 days
Amreli	Once in 5 days
Porbander	Once in 2-3 days
Junagadh	Once in 3-4 days
Jamnagar	3-4 days a week
Bhavnagar	5 days a week

Source: H Mehta 2003, Saurashtra gears up for yet another parched summer, Times of India, New Delhi, 12th April, p 11

In southwest Delhi, which harbors several densely populated colonies; sweet groundwater is on the verge of drying up. Deep boring will be useless as there is hardly two meters of sweet water left. These two examples are but a sample of the problems being faced in urban India today.

The situation in rural India is even worse. Wells are drying up and villagers; particularly women and children have to walk to increasingly longer distances to access a bucket of water. Though several million dollars have been spent on water supply schemes, there has hardly been a decline in the population that does not have access to water.

While rivers have been reduced to drains, the groundwater in several regions is also of poor quality. In several states the groundwater has been found to have above permissible levels of fluoride, the consumption of which leads to deformed bones and teeth and a general decline in health, or fluorosis. Fluorosis is endemic in 19 states in India; 65 million including six million children are at risk. The amount of fluoride varies from 1 mg/litre to 48 mg/litre against a maximum permissible level of fluoride in drinking water of 1.5 mg/litre, according to WHO guidelines. In addition, arsenic is persent in the groundwater in districts of West Bengal.

There are several reports of excessive nitrate in groundwater tested from Punjab and Delhi, as well as pesticides in the river Yamuna, the source of water supply in Delhi as well as other towns. Excess nitrate consumption has been known to cause methhaemoglobinemia (blue baby syndrome) in newborn babies. Pesticides act as hormone disruptors affecting the hormonal cycle, interfere with the body's immune response as well as increase the risks of contracting cancer.

Dealing with water pollution: current practices

The issue of water pollution is usually dealt with in three ways:

By keeping the water clean in the first place. This is often not possible, specially in overpopulated and underdeveloped countries

By cleaning the water of pollutants. This is an expensive solution, which cannot be adopted by all communities. In places where there is fluoride in groundwater, filters have bee developed that remove the fluoride. Unfortunately, these filters have not been successful in the field. Problems include disposal of the filtered fluoride and knowing when the filter needs to be changed. In arsenic affected areas also, research and efforts have been directed towards removing the arsenic through filtration.

By using alternate water sources. The usual strategy has been to tap groundwater if the surface water source is polluted or to go even further into groundwater aquifers if the water is polluted at the current depth, increasing the risk of pumping up serious contaminants such as arsenic, in addition to drying up sources.

Rain to the rescue?

Rain is the primary source of water. Rainwater harvesting is now a major movement in various parts of the world today. These include developing and developed countries – Australia, Bangladesh, Brazil, the Caribbean islands, China, Germany, Japan, Kenya, India, Indonesia, Pakistan, Mexico, Singapore, Sri Lanka, Thailand and the US.

Unfortunately, hardly any attention is given to tapping rain – the primary source of water – to meet potable requirements. Examples like Rajshahi district in Bangladesh are few. Even in a country like India, where water harvesting is a major activity, in most cases, the rain harvested is used for non-potable and recharge purposes, rather than for drinking.

Rain is usually harvested for:

a) Non-potable use;
b) Groundwater aquifer recharge;
c) Reducing volumes for sewage management; and,
d) Flood management.

The reasons why its use for drinking is low range from the dependence on cost-intensive centralised piped water supply systems to a general impression that rainwater is impure and contaminated.

Drinking Rain

Rain is, since the beginning of humankind, the primary source of water. It is rain that is mostly responsible for recharging groundwater and rejuvenating rivers. It is this secondary water that is then subjected to expensive treatment to meet potable guidelines. Yet, we perceive rain to be too polluted to drink or treat.

There is thus a need to bring about a paradigm change in rainwater utilisation – from non-potable to potable use. One of the main obstacles is the over-reliance on centralised pipeline water supply systems that are expensive and not always a practical solution. The other is that of rainwater quality.

The issue of rainwater quality must be viewed in the proper perspective:

1. In places where there is no other source of water, should rainwater be ignored?
2. In places where secondary sources of water are polluted, should rain as a source of water be ignored? In Delhi for example, the river Yamuna is the source of water supplied by the municipal authorities. This river is so polluted sometimes, that the water treatment plants shut down as they can no longer deal with the pollution. In June 2003, the Chief Executive Officer (CEO) of the Delhi Jal Board (DJB), the municipal authority that supplies water, admitted that the existing water treatment plants are not capable of killing the fecal coliform in the river. The river is flooded with faecal coliform, almost 70 million in 100 ml as against the permissible limits of 2,500 per 100 ml. According to the CEO, "Upgrading the existing secondary sewage treatment plants to tertiary plants will cost about Rs 15 billion (about $ 300 million). Even the western countries cannot afford it. It's out of question for the DJB."
3. If secondary sources of water like surface water and groundwater can be purified through multi-stage technologies, why can the same not be adapted and adopted for rainwater? Will this not give a sustainable and decentralised source of clean drinking water?

The RainPC

One product that converts rainwater to drinking water is the RainPC, developed by the Dutch company AquaSure.

The RainPC is a miniature water plant, which turns rainwater into safe drinking water, by the using multistage purification treatment methods similar to those used by western municipal water treatment plants. It is an example of applying modern state-of-the-art technology for a traditional source of water – rain. The result is drinking water purified at the point of use.

Purification takes place by multi-stage (MST) process:

1. Rainwater enters the unit at the base through a pressure reduction valve and via a water meter which monitors the amount of water being purified.
2. The water flows upwards through the sedimentation base and through a specially developed pre-filter, which extracts particles larger than 0.2 mm.
3. The water then passes through three cartridges of Xenotex A and one cartridge of activated carbon containing silver particles (CAG). These cartridges purify the water using the principle of ion exchange and adsorption to eliminate inorganic contaminants such as heavy metals, as well as organic contaminants and odour, and provide the right taste. It also inhibits the possible growth of bacteria.
4. At the final stage, just before point of use, there is a micro-membrane which secures absolute filtration of bacteria.

This process thus turns rainwater into drinking water that meets WHO drinking water quality guidelines.

The features of this filter include:

a) Use of multi-stage water purification technology;
b) A filtering system that works on the principle of gravity and does not use electricity;
c) A filtering sytsem that gives an output of 40 litres per hour; and,
d) A filteringt system that offers a decentralised and sustainable drinking water supply at low cost that meets World Health Organisation water quality guidelines

The filter has been developed keeping in mind the possible pollutants that can be found in rain. Some of the pollutants that RainPC can remove are indicated in the tables below (*Table 2A, 2B, 2C: Purification performance*). In water that was contaminated by mixing with bacteral cultures, after filtration the water tested negative for bacteria (*Table 2D: Purification performance*).

Though according to WHO drinking water guidelines, the water should be free of E Coli and total coliform bacteria, this filter does remove other microbial contaminants found in rain. It however, will not remove viruses.

Table 2A: Purification performance

Removal of various contaminants by RainPC

Contaminants	RainPC
Micro-organisms	
E. Coli, faecal streptococci	99.999999%
Cysts	99.999 %
Legionella	99.999999 %
Viruses	No
Heavy metals	
Zinc	++
Copper	++
Lead	++
Cadmium	++
Inorganic compounds	
Ammonium	++
Chloride	++
Organic compounds	
Pesticides	++
Herbicides	++
Aromatic compounds	++
(PAC)	++
Taste/ odor	++
Colour(PT/Co)< 20mg/l	
Sediment	++
(turbidity< 4FTE)	

++ = fulfills WHO guidelines for drinking water

Table 2B: Purification performance

Rooftop rainwater quality in Delhi, India and whether the Rain PC can purify the water

Parameter exceeding WHO drinking water guidelines	**Permissible levels according to WHO drinking water guidelines**	**Rooftop rainwater Delhi**	**Whether RainPC can purify to meet WHO guidelines**
Ammonia (free and saline)	1.5 mg/100 ml	1.5 mg/100 ml	Yes
Coliform count MPC/100 ml	0	150	Yes
Total colony count	0	35	Yes

Table 2C: Purification performance
Contaminants found in rain and the ability of RainPC to remove these

Microbial contaminants	**Ability of Rain PC to remove these pollutants**	**Chemical contaminants**	**Ability of Rain PC to remove these pollutants**
a) *Salmonella sp*	Yes	Magnesium	Yes
b)*Clostridium perfringens*	Yes	Zinc	Yes
c)*Vibrio parahaemolyticus*	Yes	Lead	Yes
d) *Campylobacter*	Yes	Cadmium	Yes
e) *Cryptosporidium*	Yes		
f) *Giardia*	Yes		
g*) Legionella-like spp*	Yes		

Source: J Gould , Is rainwater safe to drink? A review of recent findings, http//:www.eng.warwick.ac.uk/ircsa/9th. html

Table 2D: Purification performance
Performance of the RainPC on artificial water contaminated with bacteria

Parameter	**Concentration of bacteria before filtration**	**Concentration of bacteria after filtration**	**Per cent removal**
Total coliform per 100 ml	49	Nil	100
Streptococci per 100 ml	28	Nil	100
Colony forming units per ml	10^5	Nil	100

Costing for India

A costing exercise for installing a rooftop rainwater harvesting, storage and purification system including the RainPC is given in Table 3. For a family of five, considering the useful lifespan of the RainPC as eight years, the cost of providing safe drinking water is 2 cents ($

0.02) per litre. This works out as 40 cents ($ 0.40) per family per day (*Table 3*: *Costing exercise*).

Similarly the cost of setting up a rooftop rainwater harvesting, storage and purification system using the RainPC for a community of 14 families (70 people) has been worked out. Considering the useful lifespan of the RainPC as four years, the cost of providing safe drinking water is 1.4 cents ($ 0.014; *Table 3: Costing exercise*). This works out as 28 cents per family per day ($ 0.28).

Conclusions:

Rain has tremendous potential to meet drinking water requirements. Its use to meet drinking water requirements can no longer be ignored. There is a need to rethink about water supply and rain and use it for potable purposes. If the quality is poor, the rainwater can be treated and made potable by technologies like the RainPC. The Water Supply and Sanitation Collaborative Council (WSSCC) also believes that "water supply services are more successful when people feel they are responsible for, and benefit from, them. Such approaches also lend themselves to ' scaling up.' In this context modern versions of old strategies such as household rainwater harvesting have enormous potential. The private sector in the form of local artisans, masons and small-scale manufacturers can develop and market low-cost technologies. In this way, better sanitation and water supply also contributes to the local economy."

If indeed, increasing access to household and community safe drinking water has to be achieved, the inexpensive and rapid solution lies in rain.

Table 3: Costing exercise

Cost (in Indian rupees) of setting up of rooftop rainwater harvesting and purification system

Level	Storage tank requirement (in litres)	Cost of installation in rupees (tank, piping, etc.)	Cost of rainwater purification including RainPC installation in rupees	Recurring costs in rupees (for cartridges)	Total cost in rupees	Cost per litre
Household level (family of five at 4 litres per person per day)	6,500	21,740 ($ 435)	37,785 ($ 756)	19,500 ($ 390)	57,285 ($ 1146)	Rupee 1 ($ 0.02)
Community level (for 70 persons at four litres per person per day)	90,000	1,59,375 ($ 3188)	37,785 ($ 756)	82,500 ($ 1650)	120,285 ($ 2406)	0.70 rupee ($ 0.014)

Note: Amount in brackets is in equivalent dollars; 1$ = Rs 50 approximately