IOSR Journal of Environmental Science, Toxicology and Food Technology

IOSR Journals
International Organization of Scientific Research

e-ISSN : 2319-2402 Volume : 10 Issue : 1 (Version - I) p-ISSN : 2319-2399

IOSR-JESTFT

Contents:

IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 10, Issue 1 Ver. I (Jan. 2016), PP 43-48
www.iosrjournals.org

Reinventing the Biosand Filter: An Easy Solution for Safe Drinking Water

Lalit Mohan Sharma[1], Saurabh Sood[2]
[1]*(Adaptive Technologies, S M Sehgal Foundation, India)*
[2]*(Adaptive Technologies, S M Sehgal Foundation, India)*

Abstract: *Microbes, iron, arsenic and turbidity is encountered in drinking water across numerous states in India. These contaminants could either coexist or may be present individually in water. Coexistence is largely evident in Eastern states of India. Presently, most of the population either does not use any solution of purifying water or the solution is inadequate. Thus, there is a daunting need to facilitate removal of these frequently occurring contaminants simultaneously as well as individually.*
A technological solution at point of use is preferred to eliminate the risk of secondary contamination. The technology needs to be replicable, effective and sustainable against all these contaminants. In this paper, we present an innovative model of Biosand Filter ,'JalKalp', fabricated in stainless steel so as to overcome the limitations experienced with conventional biosand filter made in pre-cast cement concrete (designed by CAWST). This model is found performing better than the conventional biosand filter. JalKalp offers increased filtration rate and better portability and production quality control. Water quality tests demonstrate its effectiveness against E Coli, Total Coliforms, Turbidity and iron contamination. JalKalp model of biosand filter discussed in the paper is found to have a wider opportunity for application and adoption in different geographical conditions.
Keywords: *Safe drinking water, Biosand filter, household water treatment, Water contamination*

I. Range of the problems

Until 2012, 748 million people in the world receive their water from an unimproved drinking water source [1]. Such households have little choice but to get their water from the same sources in which animals drink and defecate, which leads to water-related diseases such as diarrhoea, dysentery, cholera etc. An improved source of water (includes piped water, public tap, tubewell, protected dug well, protected spring or rainwater) is only a proxy indicator of safe drinking water, and is being increasingly recognized as not contamination free [2].

As a result, consumption of unsafe water across the world causes 4 billion cases of diarrhoea each year and results in 1.8 million diarrhoeal deaths, majority of which are of children under 5 years of age [3]. In India, bacterial contamination of water is a widespread problem and a major cause of illness, with 37.7 million Indians infected with water borne diseases each year [4].

Diarrhoeal diseases are caused by pathogens, also called biological contamination mainly due to lack of sanitary conditions. The geographical extent of biological contamination is spread throughout India, with no estimates available on the number of districts affected [5]. To reduce the incidence of diarrhoeal diseases, water availability from improved sources is solicited [6]. In developing countries like India, the quality and quantity of water supply is not upto the mark, especially in rural areas.

Arsenic contamination above permissible limits is found across alluvial planes of Ganges, in six districts of West Bengal [7] and more recently is being detected in north eastern region of India [8] and Uttar Pradesh. Arsenic contamination in water occurs through both natural and anthropogenic causes. It can be found in surface and groundwater through dissolution from rocks, minerals and ores or due to industrial effluents. Evidence suggests that consumption of water contaminated with arsenic is associated with development of cancer particularly skin, lung and bladder [9].

Iron is another abundant metals on earth and vital for living organisms. Presence of iron in water increases the hazard of pathogenic organisms, since many of these organisms require iron to grow. Nevertheless both deficiency and excess of iron in the body leads to health hazards like anaemia and haemochromatosis. Iron content in water over permissible limits is found across 23 districts of Bihar, Rajasthan, Tripura and West Bengal [10] . High iron content in water makes it taste astringent and may stain laundry and utensils [11].

Water borne diseases caused by pathogens have an adverse health impact and leads to malnutrition and low immunity levels. Malnutrition and low immunity may also aggravate the effect of other contaminations including arsenic in the body[1].

[1] WHO description of causes at http://www.who.int/water_sanitation_health/diseases/arsenicosis/en/

II. Contemporary Solutions

At a global scale making safe drinking water available along with improved sanitation and hygiene conditions can reduce upto 1.4 million child deaths caused due to diarrhoeal diseases [12]. Water treatment can be exercised at different stages of water delivery system i.e at source, in the public distribution system, and at household level. To ensure safe consumption of water it is essential to sensitize communities on health risks of consuming unsafe water and build awareness to safeguard water from contamination at all these stages consecutively. However, it requires elaborate infrastructure, trained operators and maintenance routines along each stage of water delivery process. Therefore, a technological solution at household level (also called point of use) is preferred, as it eliminates the risk of secondary contamination.

"Household water treatment systems are proven, low-cost interventions that have the potential to provide safe water" [13]. Use of water filters at household level are associated with greater reductions in diarrhoea incidence in low and middle income settings [14]. Household Water Treatment (HWT) technology is deployed at the last step, just before the water consumption by the user himself/herself and can be of various types like chlorination, SODIS (Solar Disinfection), ceramic filters and biosand filters. Majority of them struggle with one or another issue like cost intensive, availability issue, need of electricity, recurring costs, contaminant specific, skills etc. Table 1 is an attempt to evaluate the Point of Use filter technologies against parameters of user concern.

Table 1 Key features of existing household water treatment technologies

Design Features	Aquasif (Terracota Disc)	Steel Candle Filter	TATA Swacch	Biosand Filter	Boiling	Chlorine Drops	SODIS	Reverse Osmosis
Affordable	✓	✓	✓	✓		✓	✓	
Eco friendly	✓	✓		✓			✓	
Availability				✓	✓		✓	
Easy to use	✓	✓	✓	✓		✓	✓	✓
Time efficient				✓		✓		✓
Improves taste and temperature	✓							
Can treat								
Pathogens	✓	✓	✓	✓	✓	✓	✓	✓
Iron				✓				✓
Arsenic				✓				✓
Turbidity	✓	✓	✓	✓				✓

A likely limitation of these technologies is the inability to address a combination of prevailing contaminations. Biosand Filter is one such sustainable HWT technology that can address pathogen, iron, arsenic and turbidity simultaneously. It is potentially a successful tool against water contamination in developing countries as it has been found to be highly effective in reducing diarrhoeal disease occurrence and has high post implementation use levels as compared to other Household Water Treatment technologies [15].

III. Biosand Filter

Biosand filter is a sustainable and proven drinking water purification method. It reduces the leading causes of waterborne disease and death in the developing world through a combination of biological and mechanical processes significantly. This technology is an improvised slow sand filtration developed by Dr. David Manz of the University of Calgary, in Alberta, Canada. Evidence suggests long term and consistent results of slow sand filter technology [16].

Bio-sand filter also removes iron and suspended solid particles from water in addition to biological contaminants, and makes it suitable for drinking and other purposes. It can also be used for arsenic removal through simple adaptation. It works under the force of gravity without using of any form of energy or on line pressure.

IV. Components and Processes of Biosand Filter (BSF)

Dr. David Manz, described the process of filtration [17] that is outlined below. The filtration process in Biosand Filters is an adaptation of the slow sand filtration that enables the filter to be used on demand basis. It eliminates the need to construct large sized slow sand filter and to continuously operate it.

The component of the filter includes a filtering medium (sand) and an underdrain (coarse rock). Water is pooled to a depth on top of sand, and it flows downward under gravity into the underdrain where it is stored and flows out when water is poured by the user. Particulate material; and bacteria, viruses and parasites of size larger than the pore size in the water gets accumulated at the top of the sand. Some of the free floating bacteria and viruses that are small and cannot be captured through physical filtration attach themselves to the top of filtering medium (sand) to form what is called 'biolayer'. Other than this biological process, through adsorption bacteria and viruses stick to the slightly electrostatically charged sand particles in the filtering medium. These living microorganisms feed (or predate) on both living and dead organic matter that enter through water poured into the filter with each use. Remaining microbes are unable to survive in the lower section of the filtering medium that has anaerobic conditions, devoid of oxygen and light.

V. Innovation Design Of Jal Kalp

Conventional biosand filters (See Figure 1) are made of pre-cast cement concrete, which is prone to breakage and low quality and rate of production, inconsistency issues, and difficulty in transportation to remote villages on rural roads and undulating hilly tracks because of heavy weight.

Some of the common quality issues in concrete bio-sand filters are due to variations in quality of construction material, and manufacturing faults. Further, the concrete filter body is prone to cracks or breakage, efflorescence due to salts present in water. The edges of the filter are likely to chip off easily during transportation of the heavy filter on bumpy rail roads. It makes it difficult and risky to transport in remote or hilly rural locations. Issues in portability due to weight (75 Kg), low rate of production due to need of mould for casting, and quality control in production of concrete bio-sand filters-- triggered Sehgal foundation to design and develop bio-sand filter in another material.

Figure 2 Conventional Biosand Filter design

Figure 1 Newly developed JalKalp Filter

Prototypes of biosand filter in different materials including plastic, fibre glass, galvanized iron (GI), and stainless steel were developed and tested. As a result of which the newly developed lightweight design of biosand filter is made up of stainless steel biosand filter and named -JalKalp (see Figure 2). It weighs 4.5 kgs and overcomes shortcomings of conventional biosand filter to provide better quality control. Besides adding to its looks, stainless steel adds to the strength, reliability, and durability of the filter. It is easy to transport to remote and hilly locations.

In this paper we present the results of tests conducted on water passed through JalKalp Filter to assess the efficiency in removal of biological contamination and iron in water. . The test for presence of coliform bacteria (include any type of bacteria that live in the colon or the intestines of humans and other animals e.g. E. coli) is conducted. Tests for specific harmful viruses, protozoa and bacteria is time consuming & expensive and this methodology is generally accepted to be a valid test for water contamination because [18] a) Coliforms may be associated with the sources of pathogens contaminating water and their presence in drinking water indicates a possible presence of harmful, disease causing organisms b) The analysis of drinking water for coliforms is relatively simple, economical and efficient. The results of the pilot tests are discussed in the following section.

VI. Water Quality Tests

Water quality tests were conducted to assess the pathogen removal efficiency of Jal kalp filter over a period. The parameters for water include iron, total Coliform test and test for detecting presence E Coli. Jal kalp filter after installation was also fed with diluted sewage water. The tests were conducted through a NABL accredited and ISO 9001 certified, CRISIL rated Laboratory.

The trend in efficiency of removing coliform from raw water is found to have improved to 95% on the 7th day of installation (See **Error! Reference source not found.** and Table 2). From 7th day onward the improvement is incremental upto 98.5% till 20th day and remains static thereon. Removal of E.coli from raw water was 100% from day one and continued till day 20.

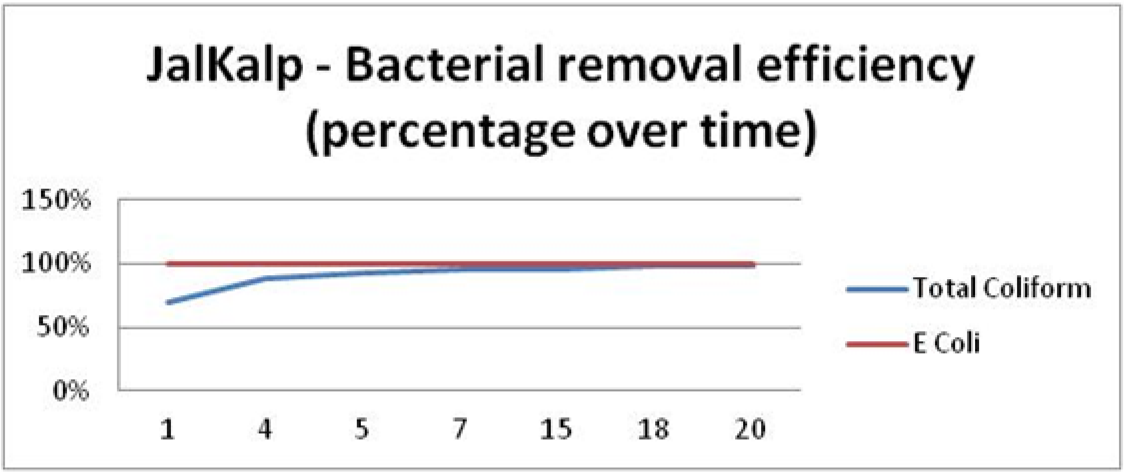

Figure 3 JalKalp bacterial removal efficiency

Table 2 Schedule and results of water quality test

Sampling Date	Days after installation	Total Coliform			E Coli		
		Raw	Filtered	% Removed	Raw	Filtered	% Removed
21-04-2015	1	350	110	69	4	0	100
24-04-2015	4	500	60	88	7	0	100
25-04-2015	5	900	70	92	12	0	100
27-04-2015	7	1600	80	95	17	0	100
05-05-2015	15	350	17	95	4	0	100
18-05-2015	18	460	11	98	7	0	100
20-05-2015	20	210	3	98.5	3	0	100

Copper is increasingly known for its biocidal properties. Its use as a disinfectant is not new and has been put to use for over centuries. Copper ions, either alone or in copper complexes, have been used for centuries to disinfect liquids, solids and human tissue. Recent studies have highlighted the antimicrobial properties of copper and its alloys against a range of different bacteria. These studies have documented antimicrobial effect of copper against a range of clinically important pathogens. As a result, it has been found to be useful to control the spread of hospital acquired infections [19] and for storing potable water [20].

In order to achieve total coliform removal percentage target of 100% an adaptation in the JalKalp filter was also introduced where in small pieces of thin copper sheet having total surface area of 6 square centimetres was inserted in drainage zone through the outlet spout. And the performance of the filter was tested in terms of reduction in Total Coliform and E Coli. Results are shown in Table 3. The results reveal introduction of Copper as an adaptation to JalKalp filter to be highly effective in removing both total coliform and E coli from contaminated water.

Table 3 Water test results after introduction of copper in drainage zone

Sampling Date	Days after installation	Total Coliform			E Coli		
		Raw	Filtered	% Removed	Raw	Filtered	% Removed
24-07-2015	85	350	0	100	9	0	100
06-08-2015	98	240	0	100	7	0	100

In addition to the above parameters, Jal kalp filter is also noted to remove iron content from raw water. Two observations of iron presence in

Table 4 show an average of 99.9% removal of iron content from raw water. Further tests need to be conducted on water with higher concentrations of iron, to validate the effectiveness of Jal kalp in removing iron contamination.

Table 4 Results of Iron removal efficiency

Sampling Date	Days after installation	Iron		
		Raw	Filtered	% Removed
20-05-2015	20.00	1.9	0.25	99.98

06-08-2015	98.00	0.28	0.01	99.99

VII. Conclusion

We at Sehgal Foundation are very pleased with the promising water quality results of the newly developed JalKalp filter. The improved version JalKalp biosand filter is also evaluated against the criterion suggested by Sobsey and colleagues [21] (shown in Table 5).

Table 5 Criteria for sustainability of point of use water treatment technology

Sl. No.	Criteria	Performance of Jalkalp
1	Ability to produce sufficient amount of safe treated water to meet the daily household needs	JalKalp filter can treat 18-20 litres in each pour. Average family need less than this for cooking and drinking
2	Effectiveness in treating water with specific contaminants	Tests indicates that JalKalp filter has removed disease causing pathogens
3	Small user time to treat water	The filtration rate of JalKalp filter is 0.75 litres/minute
4	Low cost	JalKalp filter costs 3000 INR and zero operation and maintenance cost
5	Availability of reliable, accessible and affordable supply chain for maintenance and replacement parts that is required for any such unit to sustain	Jalkalp filter is replacement free and requires simple maintenance routines that the user can do without external support (see Box 1)
6	Sustained adoption and use after installation	Our field experience suggests high rates of adoption and use after installation

As there is no moving part, Biosand filter does not require any replacements. With time the flow rate of filtered water may be reduced. It happens due to accumulation of silt (came with water) over the sand top layer. When the flow rate slows down, then one may have to lift off the lid, pour water in the filter, take out the diffuser trough, and do a "swirl and dump" which means gently swirling the water above sand top layer and removing the cloudy water above the sand. This may be repeated 3 or 4 times to "clean" the top layer of accumulated silt and the filter starts working at normal filtration rate.

Box 1 Suggested maintenance routine for JalKalp Filter

The newly developed JalKalp filter is found to effectively treat the issue of water contamination at household level and is scalable to address common and widespread occurring water contaminants - thereby promote community health by reduction of waterborne diseases.

References

[1] WHO and UNICEF, Progress on sanitation and drinking water joint monitoring programme update 2014 (World Health Organization (WHO),Geneva, Switzerland, 2014).
[2] Ibid 42.
[3] WHO-Geneva, CH. International Network to Promote Household Water Treatment and Safe Storage ,Combating waterborne disease at the household level (World Health Organization(WHO, Geneva, Switzerland, 2007).
[4] Indira Khurana and Romit Sen, Drinking water quality in rural india: issues and approaches, WaterAid India, 2008
[5] P.S.V. Shankar, H. Kulkarni and S. Krishnan, India's groundwater challenge and the way forward, Economic and Political Weekly, xlvi(2), 2011, 37–45.
[6] E.Guchi, Review on slow sand filtration in removing microbial contamination and particles from drinking water, American Journal of Food and Nutrition, Vol. 3(2), 2015, 47-55.
[7] M.D Kumar and T. Shah, Groundwater Pollution and Contamination in India : The Emerging Challenge. India Water Portal, 2006.
[8] D. Saurav et al., Groundwater arsenic contamination in north eastern states of india, Journal of Environmental Research and Development, 9(3), 2015, 621.
[9] World Health Organization(WHO), Arsenic in drinking-water. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, 84, 2004, 41–267.
[10] Ibid [7].
[11] Central Ground Water Board, Concept note on geogenic contamination of groundwater in india (with a special note on nitrate) (Ministry of Water Resources Govt. of India, Faridabad, India,2014).
[12] World Health Organization,How does safe water impact global health, 2008, Available at: http://www.who.int/features/qa/70/en/index.html, Accessed on December, 2015.
[13] B.D.S. Lantagne, R. Quick and E.D. Mintz, Household Water Treatment and Safe Storage Options in Developing Countries A review of current implementation practices, Woodrow Wilson International Center for Scholars, 2006
[14] J. Wolf et al., Systematic review: Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: Systematic review and meta-regression. Tropical Medicine and International Health, 19(8), 2014, 928–942.
[15] M.D. Sobsey et al., Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world. Environmental Science and Technology, 42(12),2008,4261–4267.
[16] W.F. Duke et al., The use and performance of BioSand filters in the Artibonite Valley of Haiti: a field study of 107 households, The International Electronic Journal of Rural and Remote Health Research, Education, Practice and Policy, 6, 2006, 570.
[17] D.H. Manz and P. Eng, BioSand Water Filter Technology, 2007 1–38. Retrieved from https://wiki.umn.edu/pub/EWB/Uganda_Groundwater_Supply/BSF_Design.pdf
[18] S. Sarsan, Effect of storage of water in different metal vessels on coliforms. International Journal of Current Microbiology and Applied Sciences, 2(11), 2013, 24–29.

[19] S.J. Gould et al., The antimicrobial properties of copper surfaces against a range of important nosocomial pathogens. Annals of Microbiology, 59(1), 2009,151–156.
[20] Ibid[18].
[21] Ibid[15].

Acknowledgement
The authors would like to thank Dr Suri Sehgal and Jay Sehgal for their encouragement and motivation to initiate and develop this innovation; and to Mr Salahuddin Saiphy and Ms Puja O Murada for their valuable inputs. The entire team of Sehgal Foundation deserves special thanks for their support in the overall process.

PROFILE OF Lalit Mohan Sharma
Lalit Mohan Sharma is Director, Adaptive technologies at SM Sehgal Foundation. He is a graduate civil engineer and holds a Masters of Technology (Management & Systems) from Indian Institute of Technology, Delhi. Under his leadership SM Sehgal Foundation's water management program has been recognized widely. The organization has won UNESCO-Water Digest 'Best Water NGO' award for 'Revival of Rural Water Resources in 2009 and 2010 and 'Best Water NGO' for 'Rain Water Harvesting' 2008 and 'Ground Water Augmentation Award-2010' from Ministry of Water Resources, Government of India in 2011, FICCI Water Award 2013: first prize under NGO category for excellence in water management and conservation, 'Water Conservation Award-2013' from The Institution of Engineers (India). He has presented several papers on issues related to integrated and sustainable development of water resources and sanitation. His innovation 'Creating Fresh Water within Saline Aquifer' was selected by United Nations Organization for showcasing at Solutions Summit – 2015 and he was invited to make a presentation on this innovation at UN Headquarters, New York in Solutions Summit – 2015.