MEASURING THE HEALTH IMPACT OF BIO SAND FILTERS AND DISSEMINATION OF TECHNOLOGY

STUDY REPORT

Gravis

People for Progress in India

Measuring the health impact of Bio Sand Filters and dissemination of technology

Study Report

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ppi People for Progress in India

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Study Report

Location and coverage of the study

10 villages of Phalodi of Jodhpur district, India

Study duration

18 months

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ISBN 978-81-970765-9-6

Financial Support by

People for Progress in India (PPI), USA

Printed by : **Indian Map Service**, Shastri Nagar, Jodhpur, Phone : 0291-2612874

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FOREWORD

The quality of drinking water has continued to be a major public health and developmental challenge in many parts of the world, especially in the rural regions and for the people living under poverty. The Thar Desert region of Rajasthan in India is one such region where amidst chronic droughts over a long period of time, the communities are forced to live with unsafe and contaminated water leading to a number of health issues and significantly contributing to an overall poor socio-Economic Development.

GRAVIS, a well recognized Non-Governmental Organization (NGO) of the Thar Desert, has worked relentlessly over the last 34 years to enhance drinking water availability in the rural areas. For many years, GRAVIS has been keenly working on improving the quality of drinking water through various methods. About three years ago, with the support of People for Progress in India (PPI), USA, GRAVIS introduced Bio Sand Water Filters (BSFs) in the Thar Desert. The response received and the immediate impact of the filters was quite positive. Moving forward, it was thought of measuring the impact and learning through a study organized by GRAVIS and financially and technically supported by PPI, USA.

With the support of PPI, USA GRAVIS organized the study with an overall goal to research the impact of water filters on people's health with evidences and to disseminate the technology for a wider replication. The study team interacted with user households in 10 study villages and the findings of the study are summarized in this report. We hope that the learning is useful for us and for the communities of the Thar Desert in the context of understanding water and health and the role of filters. It is envisaged that other stakeholders including NGO, Government bodies and communities in general in the Thar Desert and beyond could also use the learning.

We thank PPI, USA for the financial and technical support for the study and the Thar Desert communities for their active support and participation.

GRAVIS team

CHAPTER 1 - THE PREMISE

1.1 Introduction and background

Global Scenario

One of the most important foundation stones for the civilizations to grow historically has been proximity to a water source of good quality, which is a crucial need for human consumption as well as for agriculture or food production systems. With the availability of water, communities around the world have grown and developed as societies. Water is inevitably important for survival and for human development.

Safe drinking water is the foundation of healthy life and for healthy communities. Lack of clean water supplies in households particularly in rural areas is a critical developmental challenge faced by communities worldwide. According to statistics, almost 2.1 billion people of the world do not have access to safe water and 4.5 billon people have not access to adequate sanitation. At an estimate, more than 842,000 people die each year from water related diseases.[1] Lack of access to clean water and basic sanitation is the leading cause for diarrhea and diarrheal death around the world, especially impacting rural children.

In recognition of water and sanitation's significant importance in development, the United Nations General Assembly (UNGA) recognized the human right to water and sanitation in the year 2010.[2] The UNGA acknowledged that access to clean drinking water and sanitation are essential to the realization of all human rights. Every human has the right to sufficient, continuous, safe, acceptable, physically accessible, and affordable water for personal and domestic use.

Yet, a large number of people worldwide are forced to live without a clean source of water and with no or very poor sanitation arrangements. The World Health Organization estimates that about 2 million deaths occur in a year due to waterborne diseases caused by unavailability of safe drinking water and sanitation.[3] A significant proportion of diarrheal death occurs in children under 5. Unsafe drinking water and inadequate sanitation accounts for about 88% of diarrheal death globally.[4] In the water sources, various contaminants of biological and chemical forms pollute drinking water causing the ill impacts on human health. The situation is particularly grave in rural areas and urban slums where poverty is prevalent and water and sanitation are critical challenges. Further, unsafe and contaminated water is a major cause for various Neglected Tropical Diseases such as Guinea Worm Disease, Trachoma and Schistosomiasis.[5]

Women and girls face the water and sanitation challenges most directly and severely. There is a clear link with fewer girls attending schools as result of water fetching drudgery and because of proper sanitation arrangements for girls within the schools. According to the United Nations Millennium Development Goals Report 2007, out of the 72 million children not enrolled in primary schools, 57% were girls from poor households.[6] Lower literacy rates and women and an overall poor health status of women around

[1] http://www.who.int/mediacentre/factsheets/fs391/en/
[2] http://www.un.org/waterforlifedecade/human_right_to_water.shtml
[3] WHO. Health and sustainable development.
[4] http://apps.who.int/iris/bitstream/10665/43840/1/9789241596435_eng.pdf
[5] http://apps.who.int/iris/bitstream/10665/69367/1/WHO_CDS_NTD_2006.2_eng.pdf
[6] http://www.un.org/millenniumgoals/pdf/mdg2007.pdf

the world are largely caused by water and sanitation related challenges.

The situation in India and in the Thar Desert

Amidst many challenges that India faces in the context of human and socio-economic development, lack of potable water and inadequate sanitation is a significant barrier. While the water availability situation varies in India quite significantly in different regions with a very wide range of rainfall and climatic conditions, the overall situation on water quality and on the sanitation status remains a national challenge across the country.

Post India's independence in the year 1947, according to Government data, substantial progress has been made on increasing the population coverage with drinking water supply reaching to about 80% of the national population.[7] Yet, India is one of the 10 countries in the world with the highest number of people without an improved source of drinking water.[8] According to a WHO estimate, India accounts for about 90% of people practicing open defecation in South Asia and for about 59% globally.[9] In absolute numbers, more than half billion people in India practice open defecation, which is a very serious developmental and public health challenges. Not surprisingly, the prevalence rates of waterborne diseases in India are very high. It is estimated that about 2,000 people die in India every day due to diarrhea[10], and about 21% of all communicable diseases in India are waterborne[11].

The situation is particularly alarming in remote and rural parts of the country where the water availability in the first place is very challenging. Women and girls face the consequences of water and sanitation problems most severely in India resulting into poor health status and lower enrolment of girls in schools.

The Thar Desert

[7] https://www.unicef.org/publications/files/pub_wes_en.pdf
[8] https://www.unicef.org/media/media_45481.html
[9] http://www.who.int/water_sanitation_health/monitoring/jmp2012/fast_facts/en/
[10] http://www.cseindia.org/userfiles/CSE-Nitya%20Jacob_khulna.pdf
[11] http://www.who.int/mediacentre/multimedia/2002/ind_sanitation/en/

The Thar Desert is the most water deprived region in India and is one of the driest arid zones worldwide. In the recent years, including in 2015-16, India faced a severe nationwide drought situation causing crop loss and a severe water shortage. India's large agricultural sector, which employs 60% of India's workforce, largely depends on the monsoon rains, which have become very unpredictable over the years as a result of climate change consequences. Wetter region of the country are becoming wetter and drier are getting further drier[12]. Thar Desert has always been the most significantly impacted region of the country at the hands of drought with severe water scarcity. In Thar, extremely limited annual rainfall (up to 6 to 8 inches in a year) and adverse weather conditions have left the region water-deprived, arid and under-developed. Impacted by chronic droughts and severe food, water shortages, Thar is one of the least developed regions and hence the communities of Thar live under poverty and with under-development. The availability of drinking water, the quality of water and sanitation facilities are serious gaps for more than 25 million inhabitants of the Thar Desert. While water shortage does impact everyone tremendously, the vulnerability and the degree of that impact multiply for the women, girls and elderly. Lack of water and poor quality of water combined with poor sanitation arrangements put the health status of these communities at great risk with a clear evidence of high morbidity and mortality caused by water.

GRAVIS' work on water

Gramin Vikas Vigyan Samiti (GRAVIS) or Center of People's Science for Rural Development was founded in 1983 by a group of Gandhian development activists in the Thar Desert of India. The organisation was formed in order to organise rural development activities in the remote parts of Thar Desert. The organisation has great faith in working on issues related to human rights, equality and rural development with active participation of rural communities of the region where in functions. In the beginning, it started its work in a cluster of 20 villages of Jodhpur district in Rajasthan. At present, GRAVIS works in more than 1,250 villages of 8 districts of the Thar Desert of Rajasthan, India, and in Uttarakhand and Uttar Pradesh States covering a population of about 1.3 million people.

In active partnership with the local communities, GRAVIS has taken up important interventions to address water and sanitation situation in Thar. The key activities and accomplishments of GRAVIS are:

- Construction of water harvesting tanks (taankas) to ensure water security at the household level. Till date, over 6,800 taankas have been constructed.
- Construction of percolation wells or beries. Till date, 599 beries have been constructed.
- Construction and renovation of over 270 village ponds.
- Introducing methods to keep the water clean in storage structures.
- Improving sanitation practices and health seeking behaviour through an outreach health education programme.
- Provision of outreach and hospital medical services to cater to people suffering with waterborne diseases and conditions arising due to lack of sanitation.
- Constructing low cost toilets.

[12] https://www.scientificamerican.com/article/indias-drought-highlights-challenges-climate-change-adaptation/

- Installation of over 300 Bio Sand Water Filters (BSF) for safer water.
- Organization of Water, Sanitation and Education (WASHED) programme in over 80 schools of Thar Desert.

For the last few years, GRAVIS has been actively addressing water quality aspect and has recently taken up an initiative of demonstrating and disseminating BSF technology in the Thar Desert, in partnership with PPI. Under the project, 260 BSFs have been installed in rural areas providing clean drinking water to users. This study assessed the effectiveness of 200 BSFs.

In the rural context of Thar Desert where most villages characterized by extreme poverty, where there is no electricity and education levels are also much lower than the state and national average[13], BSFs have been found to be more advantageous over others other techniques for purification of water to make it safe for drinking. Use of BSFs does not require electricity, technology is simple to understand and maintenance is also easy. BSFs do not have unwanted implications and costs as in the case of other economical techniques of water purification such as boiling that requires fuel and use of chlorine tablets that leave odour in water. Further, most of the communities that GRAVIS works with are dependent on rainwater for domestic needs, for which BSF is an effective purification technique as compared to groundwater. A combination of all these factors make BSFs as most economical, sustainable and suitable option for cleaning water that can be used for drinking.

Water contamination and its impact on health

The depleting ground water level is a serious issue in India, since it accounts for about 85% of the water supply nationally. In India, where groundwater is utilized intensively for irrigation and industrial purposes, a variety of land and water-based human activities are causing contamination of this valuable asset. Appendix 1 detail main drinking water sources (Main source of drinking water 2001-2011-see **Appendix 1**).[14]

There are various forms of chemical contamination that are prevalent in India. It is estimated that, about 66 million people have to drink water with a high rate of fluorides (>1.5 ppm). Higher fluoride levels can cause fluorosis – a serious health condition adversely affecting teeth and skeletal system. The excessive use of chemical fertilizers by farmers, as well as the indiscriminate disposal of human and animal waste on the land leads to a high nitrate level in the groundwater, which can also make water hazardous for human health. Arsenic is another common chemical pollutant in groundwater. Additionally, the increased levels of TDS and iron in the groundwater are also of great concern[15].

The biological contamination of drinking water is more common in India. Various pathogenic microorganisms including bacteria, helminths and viruses contaminate water, particularly surface water in smaller and large reservoirs. Biological contamination is significantly responsible for communicable, waterborne diseases and is the leading cause for diarrheal morbidity and mortality especially among children and women.

[13] Rajasthan has literacy rate of 67.1% as against national average of 70.04% and lowest female literacy rates (52,66%) in the country, http://censusindia.gov.in/2011.

[14] http://censusindia.gov.in/2011census/hlo/Data_sheet/India/Drinking_Water.pdf2012

[15] WHO India, Drinking water quality in India, WHO Report, India. (http://www.whoindia.org/LinkFiles/SDEWorkshop_Water_Quality_In_India_MOH.pdf)

In the study area the fluoride level is quite high (more than 6.00 ppm) in ground water which causes fluorosis (dental and skeletal forms). In the study area, 41% of the people found with symptoms of fluorosis, and about 27% of the children's teeth resembled "fluorosis teeth". Chemical contamination also may cause skin diseases and disorders like dermatitis, eczema, rough & cracked skin, brittle nails and rough hair. In the study, 47% of the respondents reported suffering from such kind of skin problems and 32% reported eye & ear problems related to water.

With a view to assess the impact of Bio sand Filters on the lives of people in the Thar Desert, a study was conducted. Duration of this study was 18 months and it was conducted on ten villages where BSFs were provided by GRAVIS.

1.2 Objectives of the study

The overall goal of this study is to research the impact of BSFs on people's health with evidences and to disseminate the technology for wider replication.

Specifically, the study's aims were:

- Understanding the acceptance of BSFs at ground level.
- Measuring the health impact through a research study in the context of prevalence and reduction of waterborne diseases.
- Educate other organizations within the Thar Desert region willing to work with the filters.
- Disseminating the research findings widely for replication across the Thar Desert and in other parts of India potentially.

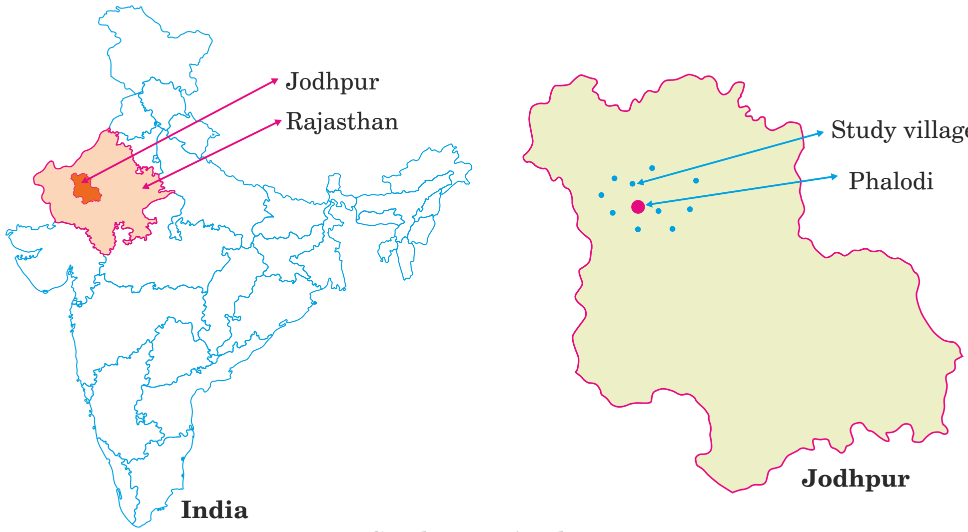
1.3 Geographic coverage and sample selection

The Thar Desert also known as the Great Indian Desert is a large, arid region in the northwestern part of the Indian subcontinent. It is the world's 17th largest desert, and the world's 9th largest subtropical desert. In India, it covers about 320,000 km2 (120,000 sq. miles), forming approximately 10% of the total geographic area of the country. More than 60% of the Indian Thar Desert is located in the state of Rajasthan. Water scarcity plays an important role in shaping life in all parts of Thar. Potable groundwater is also rare in the Thar Desert. Supplies are often sour due to dissolved minerals and are only available deep underground.

The study was designed to evaluate the newly installed BSFs' use and their impact on community health. The study area was selected in the regions of Thar Desert within Phalodi and Bap blocks of Jodhpur district. A survey was conducted among rural communities of the Thar Desert. The data was collected from the study villages between July 2016 and August 2017, over a period of about 14 months. Monthly health updates from the beneficiaries obtained to understand the change in the health status as reported by respondents.

Households (HHs) in the desert regions have a limited access to drinking water. They use naadis, taankas, tube-wells and beries. However, these HHs rely heavily on rainwater harvesting structures, on surface water and on bringing water from nearby tube-wells. The list of 10 surveyed villages is given below:

- Rahda
- Kalran
- Dhadhu
- Sanwariz
- Nagnychya Nagar
- Baigati
- Shivpura
- Badidhani
- Ugras
- Hopardi



Study area in the map

1.4 Methodology and data collection

The study used both quantitative and qualitative data collection methods. The methods involved user HH questionnaires as well as Focus Group Discussions (FGD) with a small group of villagers. The questionnaires were prepared to collect information from BSF beneficiaries at HH level. Formal meetings were conducted with the local health providers and other village stake-holders to get a better understanding of the health status of the users.

HH selection and sample size

A cross-sectional study was performed from June 2016 to August 2017 in 10 villages as already mentioned. A set of questions was prepared for the BSF beneficiaries. The questions aimed at getting information on interviewed persons' socio-economic status, sources and availability of water, cost and quality of drinking water, usefulness of BSFs and its impact on health.

In the 10 study villages, 200 HHs were provided with BSFs. User HHs for the filters in each village were selected by Village Development Committees (VDCs). All 200 user HHs participated in the study. User HHs were given an option to participate in the study throughout the year and were allowed to leave the study at any point, if they chose to do so. It was a satisfactory achievement to note that all of them cooperated and participated actively throughout the entire study period. Women were given priority to be active participants and to provide information due to their closer links with water and filters.

FGDs and semi structured interviews

During the FGDs, conversations were held in each of the study village with groups of 15-20 people including representatives from village governance bodies, Community Based Organizations (CBOs) members, social activists and community members. Information was gathered on general perspectives on provision of health facilities, availability of potable water, safe practices regarding the use and benefits of using BSFs.

Semi structured interviews were conducted with local health service providers in order to gather information regarding the prevalence of waterborne diseases in the study area and the impact of using BSFs on the health status of the villagers.

BSFs: demonstration by beneficiaries

During the field visits, the study team clearly observed the knowledge level and vigilance of the user HHs regarding the use and maintenance of the installed BSFs. In accordance with that, our team randomly visited 20 beneficiaries of the study villages and requested them to give a direct demonstration of how they are using and maintaining the BSFs. The study team checked the places where the filters are kept and how the users were using and maintaining them.

Water quality tests

The water quality testing was performed with water from various sources. The study team collected the water first directly from influent (source) like naadis, taankas, taanklis, beries and tube-wells and then the study team collected water from effluent sources (filtered water from BSFs). A small number of water samples was collected and transported to a qualified laboratory where they were analyzed in accordance with the National Rural Drinking Water Mission (NRDWM) of Government of India's standard methods. Membrane filtration was the method used to analyze the water quality. Due to budgetary restrictions, the team analyzed only a few samples. Such results are useful as an indicator of the quality of influent (source) and effluent (filtered) water at the time of testing. These results are then used to calculate the bacteria removal efficiency of BSFs and when taken together it gives a general picture of how the filters are performing in provision of safer supply of drinking water for participating HHs in the community.

1.5 Sources of drinking water and their accessibility

Given that piped water still remains elusive for the impoverished communities in the Thar Desert, rains and ground water are the two major sources of water for rural population. A relatively smaller proportion of population has access to tube wells that require electricity; and some access water through hand pumps. Contamination of ground water and its salinity renders harvesting of rainwater as the safest and most viable option for rural community.

In the Thar Desert, naadis, taankas, taanklis, and beries are the traditional water harvesting systems. They serve the essential water requirements of the communities, especially in the water deficient rural areas where rainwater is scare and yet is the main source of water.

Rainwater harvesting structures promoted by GRAVIS in the Thar Desert

Following are the commonly used and GRAVIS promoted rainwater harvesting structures in the Thar Desert[16]:

This method for collecting water consists of a covered cylindrical tank with the capacity to store between

[16]http://gravis.org.in/index.php/our-work/water-security

Taankas

A taanka

18,000 and 20,200 L of water. Water is gathered in one of two ways: either a rooftop catchment which pipes water into the unit, or a groundwater catchment area where water pours in through an opening on the side.

Taanklis

Taanklis are small water storage structures constructed within the HH premises. The water stored in it can fulfill the need of the HHs for about one month. The storage capacity of a taankli is about 3,000 to 4,000 litres of water.

A taankli

Naadis

A naadi

Naadis are natural collections of rainwater which provide an open source of water to entire villages. Unfortunately, if not kept up properly the ponds can become silted and unusable. In order to remove silt and debris, we have been building short loose rock structures in the water pathway to the naadi to keep gravel, sand, and other material from entering the pond. Local materials are used and much of the labour is done by villagers voluntarily. These rocky borders also help to replenish the soil outside the naadi with moisture and fertile topsoil. Natural vegetation grows easily in these areas and helps to further reduce soil erosion and silting of the naadi. A medium sized naadi provides a community with water for 2-6 months in a year of average rainfall, whereas big ones carry water all year round.

Beries (percolation wells)

These large underground water storage percolators are covered with a concrete top and gather ground water during monsoon season. One beri can store up to 500,000 L of water and does not require a pump, making it easy for villagers to fix and maintain. This traditional method of water gathering uses no artificial catchment and holds enough water to sustain a family of 10 for up to two years.

Beri

Ground water sources

Tube-wells and hand pumps are used to extract ground water.

Tube-wells

A tube-well

A tube-well is a type of water well in which a long 100–200 millimeters (3.9–7.9 in) wide stainless steel tube or pipe is bored into an underground aquifer. The lower end is fitted with a strainer, and a pump lifts water for irrigation. The required depth of the well depends on the depth of the water table. The wells require electricity to function.

Hand pumps

Hand pumps are manually operated pumps; they use human power and mechanical advantage to move fluids. A deep well hand pump theoretically has no limit to which it can extract water. In practice, the depth is limited by the physical power a human being can exert in lifting the column of water, which is around 80 meters.

A hand pump

It is to be noted that even in the areas where water becomes accessible through the use of either the ground water or harvesting of rain water, quality of water remains a major issue. Water gets contaminated biologically as well as chemically in these structures and chemical contamination is more common in underground water. The fact that the biological contamination can be addressed through BSFs, both rainwater harvesting for storage of water and BSF for ensuring safe quality of drinking water complement each other and also present a sustainable water use practice. Extraction of ground water in long run has not only pushed the water table down in an already water scarce region, chemically contaminated water is far more complicated to purify as well.

1.6 Various methods of purifying drinking water

Water purification is the process of removing biological and chemical contaminants, suspended solids and gases from water. The goal is to make water safer for human consumption (drinking water). The methods used include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination.

In the study area common methods of purification practiced at HH level are filtration, boiling and purification by chemical agents like chlorine tablets, NADCC (sodium dihloroisocyanurate), and iodine.

Chlorine tablets are halazone tablet. Its use for water purification is globally accepted and has been proven to be safe and effective. These tablets are available in Government health centers in the study area. The only drawback is that it creates very strong taste and odour, which makes water quite unpleasant to consume.

NaDCC: It is different from chlorine, it reacts within water to create free chlorine. It has no unpleasant taste and odour and therefore makes water palatable. The popular brand named Aqua tablet is available in local markets if India, but these tablets are not easily available in the remote part of the Thar Desert.

Iodine: Use of iodine tablets or iodine solution is one of the oldest forms of water purification. It makes water safer from bacteria, viruses and some cysts. However, the biggest challenge in regular practice is the colour and odour it leaves with in purified water. Iodine causes an unpleasant taste and odour, which makes water quite difficult to drink.

Boiling: It is the most effective and convenient way of water purification keeping water at vigorous and rolling boil for 1-3 minutes kills most of the bacteria and viruses. Since this method consumes considerable amounts of fuel it is not feasible for the Thar Desert communities to practice it regularly. It increases their financial burden as well.

Filtration: Filtration is the most popular and acceptable way of water purification at HH level in Thar. Many methods of filtration are used; some remove sand, grit and sediments only while very some are also capable of removing bacteria and viruses. Nevertheless, the communities living in the Thar require improved techniques of filtration to enhance the water quality and to address the health status. In the subsequent section, data about the prevalent practices for purifications of water in the study area have been discussed.

CHAPTER 2 : USERS' SURVEY

This chapter presents a profile of the socio economic characteristics of the households (HHs) and of individual respondents, and reflects on their knowledge and practices to access safe drinking water, installation and management of BSFs and the impact on the health of the respondents before and after the installation of BSFs. The study team surveyed a total number of 200 respondents in 10 selected villages. A tabulation and analysis plan was prepared on the basis of which the following analysis has been conducted and is presented.

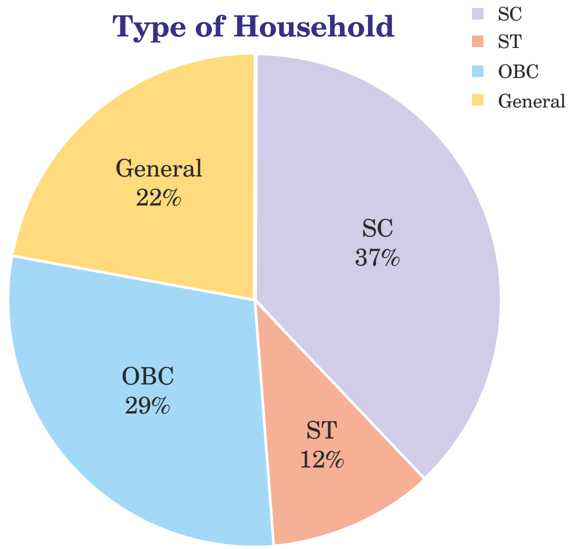
2.1 General socio- economic profile of respondents /HHs

The 10 villages of Phalodi and Bap blocks of Jodhpur District that were surveyed under the study had almost similar socio-economic conditions. An overall status of these villages is presented below.

Caste composition

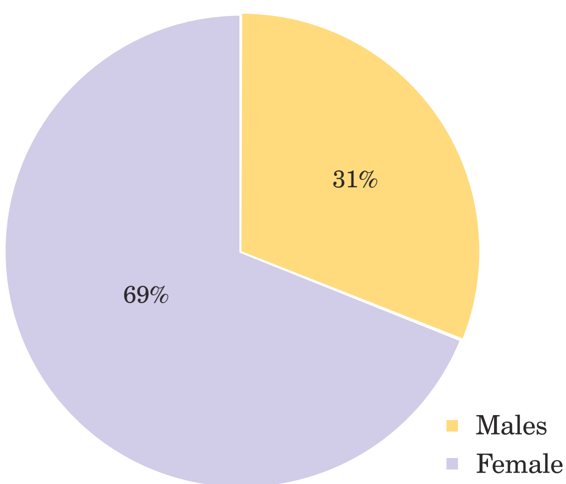
Caste composition of the HHs participating in the study comprised of four categories namely Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward Classes (OBC) and General Category. It was found that the SC, ST and OBC have limited sources of income and are socially as well as economically much weaker. **Graph 1** reveals that more than 78% of the HHs in the surveyed communities fall under SC, ST and OBC categories.

Graph 1 - Caste wise composition of respondents



Graph 2 shows majority of survey respondents were females with a 69% proportion, while males made up for the remaining 31% of respondents. Respondents were selected amongst the user HHs who participated in the interviews. The issue being water related, more number of females attended the interviews, as they are closer to HH level water management and to BSF use. The youngest respondent was 18 and the oldest one was 78 years of age. The average age of respondents was 37. The minimum age for the respondents was fixed at 18 years due to the nature of questions to be asked. Younger community members may have not fully understood the questions.

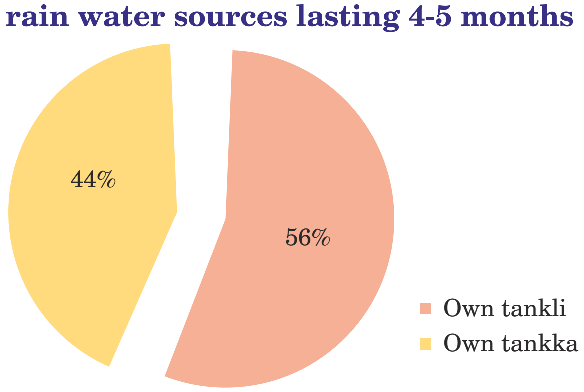
Graph 2 - Respondents (Gender)



2.2 Sources of drinking water in the study area

The study results show that 56% of the families have own taanka and 44% HHs owned taanklis which are constructed in proximity to their house. The source of water in taankas is mainly rainwater, which lasts about 4-5 months of the year.

Graph 3 - Households having access to stored rainwater through rainwater harvesting structures

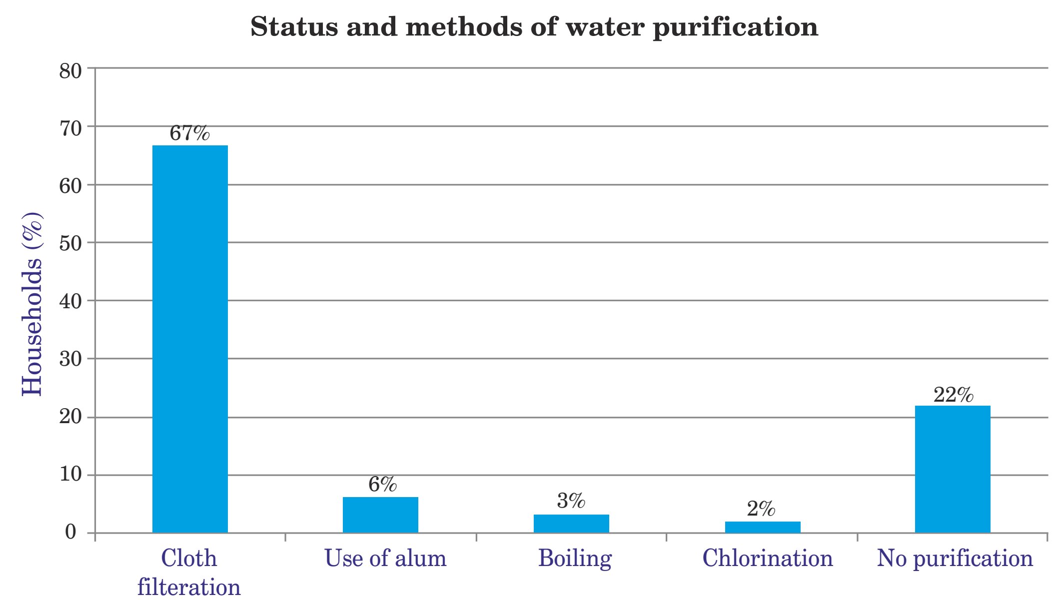


Other major sources of water are naadis and tube-wells. In the study area, 19 naadis were found in 10 villages. The study results show that there are a total of 22 tube-wells in 10 Villages. The villagers of Khara village (one of the study village) are completely dependent on naadis water because the underground water is highly saline, which cannot be used for drinking.

2.3 Water purification methods practiced

In the rural and remote areas of the Thar water is a luxury and even those who have a regular access to water resources cannot get pure water that is safe for drinking and need to purify the water before drinking. However, it is important to note here that about 22% of the households were not purifying water at all for drinking which was a matter of grave concern. The study findings note that in the ten villages water is mostly purified by the cloth filtration method. Any other kind of water treatment was not very common in the study villages.

Graph 4 - Prevalent methods of water filtration



For those treating water, cloth filtration is the most common method, amounting to 67% of respondents. There is a small portion of population using other treatment methods such as adding alum (fitkari) - 6%, boiling - 3%, and chlorination - 2%. .

2.4 Bio Sand Water Filters (BSF): A user-friendly technique at the HH level in rural areas

The BSF is an innovation on traditional slow sand water filters (which have been used for community water treatment for a long time), specifically designed for intermittent or HH use. The BSF is made of locally available materials. It consists of a simple container with a lid, enclosing layers of sand and gravel, which traps sediments, pathogens and other impurities/ contaminants from water. A biofilm, which forms as a shallow layer of water, sits atop the sand column and contributes to the elimination of contaminants.

Water is simply poured into the top of the filter and collected in a safe storage container. Pathogens and turbidity are removed by physical and biological processes in the filter sand.

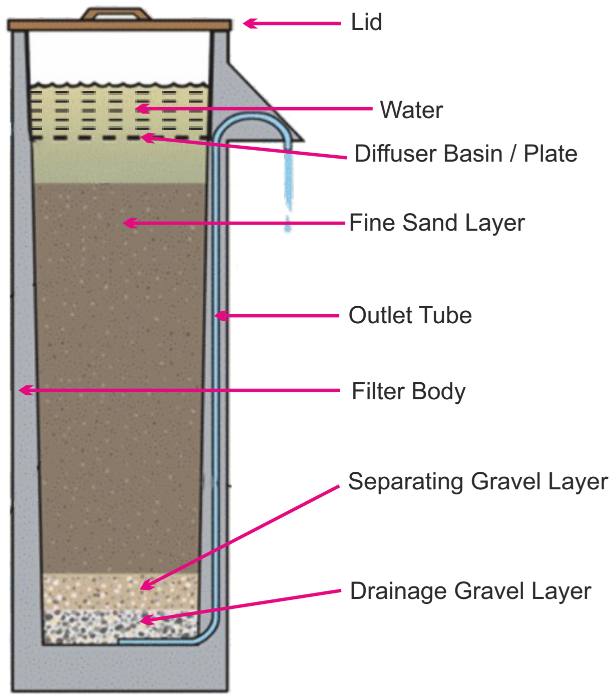


Figure 1 - Constituents of a Bio Sand Filter

Source: CAWST (2009)[17]

GRAVIS, with support of PPI, USA has provided 200 BSFs to the community and schools selected through a community led process in the study area. GRAVIS got the BSFs constructed with the help of local community members and trained them simultaneously on installation because though the construction and installation look very simple, incorrect filter design and improper installation can lead to poor filter performance. However, materials are generally locally available, technique is simple and the construction by trained local staff may create opportunities for local businesses in future.

Prior to the installation, the details about how the BSFs work were discussed with members from each user HH. After the HHs had agreed to the project terms, the filter was installed. An educational health talk including a simplified version of the technology's removal processes, maintenance and storage techniques were conducted with the villagers. Training for maintenance of the BSFs was imparted to the user HHs.

[17]https://www.biosandfilters.info/fact-sheet

The study was organized with an aim to understand the views and knowledge of the user HHs about its usefulness, affordability, benefits and to find out any possible problems encountered.

Installation and affordability

The study results and discussions notes suggest that all user HHs were quite happy to use BSFs as it was installed at a negligible cost. The material for BSFs was locally available and they themselves played an active role during the installation process, which enhanced their confidence and gave them a sense of ownership and involvement.

A filter

Capacity and ownership

Mangidevi Meghwal's family uses BSF as a resource. Recollecting the training that was provided to her and others in the family and village to the training, Mrs. Mangi said that they were told that no expenses are incurred on water purification through the filter. " Initially , I did not believe this but it is proved now as we are getting clean water every day without spending money since we started using the filter" she said.

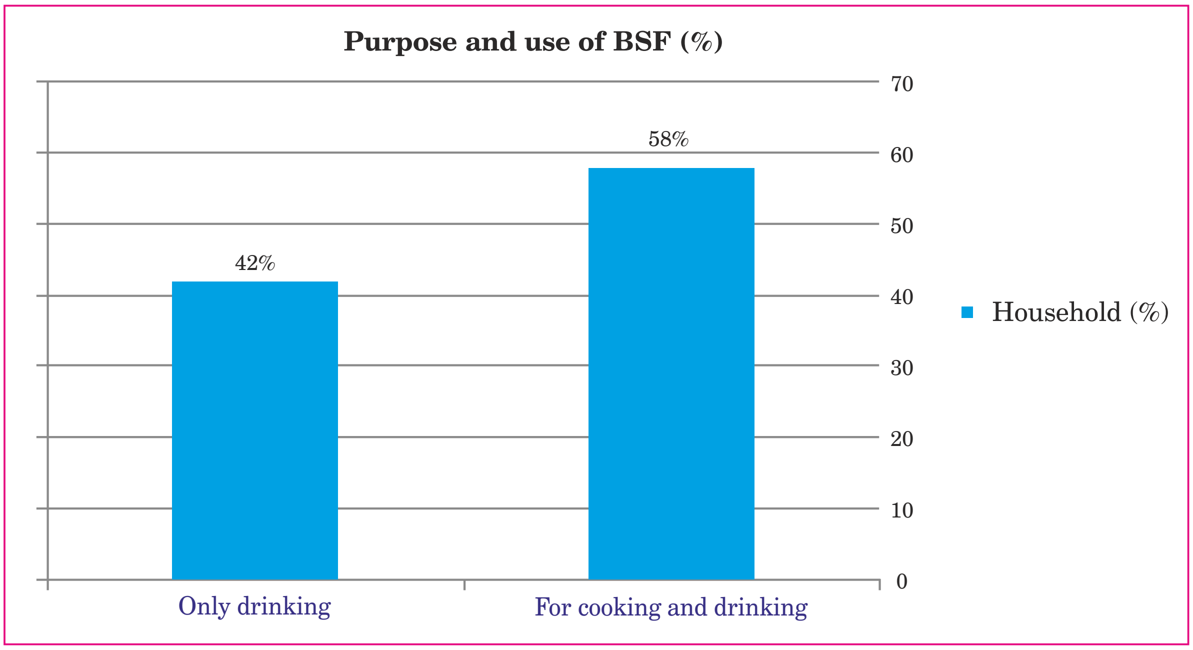
The trainings have helped the community understand not only the importance but also the technique that is used in BSFs. People are now not only using but also maintaining these BSFs independently. With the training on use of BSFs, importance of hygiene and cleanliness have also been discussed with people and there is a visible impact on people,

Talking about the sessions on cleanliness during the training Mangidevi says “we were unaware of the use of ladle and importance of keeping the pitcher at a safe and clean place. We learnt about it through the training. Now we wash the pitcher from inside as well as outside before filling it with filtered water and place it on a platform about one or two inches above the ground. We now use a ladle to draw out water from the pitcher or any other utensil. This has helped in keeping the water place clean. The algae that used to cover the ground and the pitcher is nowhere to be seen. Now the water we use is odorless. Small practices of cleanliness have resulted in hygienic environment and healthy lives for all of us”.

Operation

Since BSF is quite a simple technology with no moving mechanical parts and with no need of electricity, 100% of user HHs stated that they find operating the BSF “Easy.” While performing monthly monitoring, there were only 6% apparent cases of user HHs not properly handling their filters. With regard to the use of water, 58% reported using it for both drinking and cooking, while 42% reported using only for drinking.

Graph 5 - Purpose of BSF water

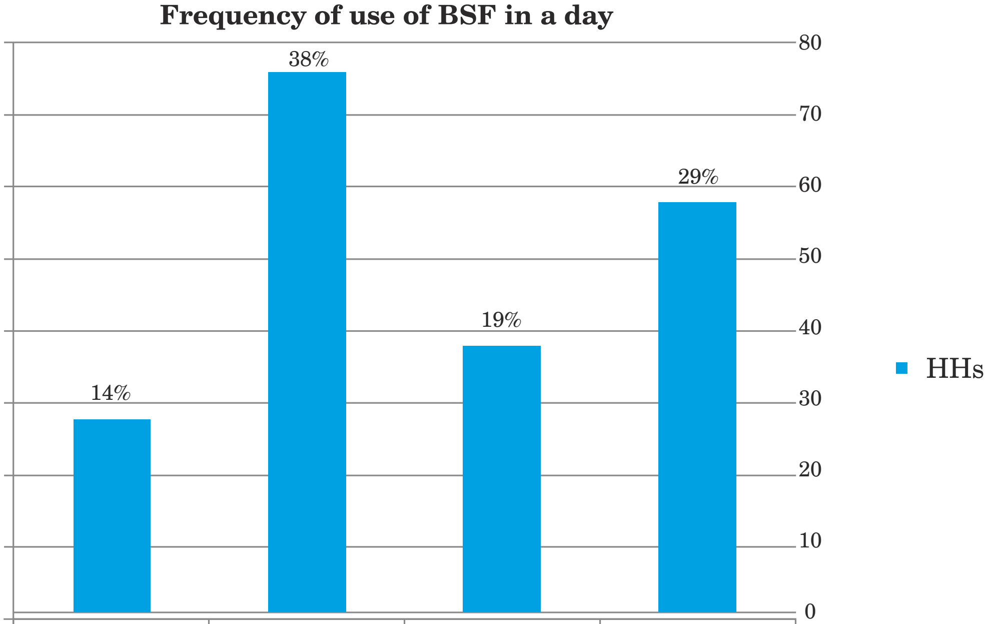


On an average with 12 members in a user HH, 5 out of 12, or 42% of the HHs reported drinking only filtered water since the installation of filters in their homes.

Frequency of use

All the HHs reported using their filters on a regular basis. Actual frequency of use was estimated during the interviews and tended to correlate directly with the size of the user HHs. The results are presented in graph 6. The graph shows the percentage of user HHs that reported using their filters once a day was 14%, twice a day was 38%, three times a day was 19% and at varying times was about 29%. On an average, each user HH used their filters twice a day (about 40 liters/day), which when calculated for the average user HH size of twelve would provide over three liters of drinking water per person. This appears to be a very realistic average rate of water consumption, and thus demonstrates user confidence in the technology.

Graph 6 - Frequency of use of BSF per day



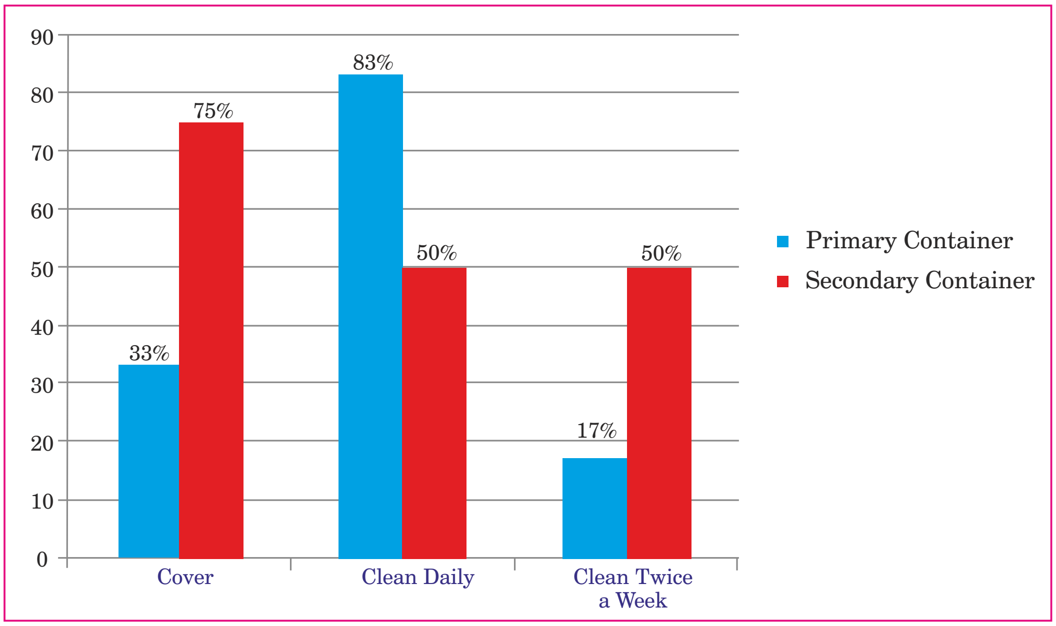
	Once	Twice	Thrice	Varying
HHs	28	76	38	58

Collection and storage

Filtered water initially gets collected in a container that is always kept beneath and is later transferred to another container for storage.

It was found that people use a variety of containers for collecting the filtered water. These include head pans and buckets of different sizes, metal pots, and locally made clay pots. The majority of the user HHs, 83%, wash their containers daily or prior to every collection, and 17% wash their container twice a week. Only 33% of the user HHs cover the collection containers to prevent recontamination of the filtered water.

Graph 7 - Collection and storage of water



However, it is to be noted that 75% of those that do not cover their collection container transfer the water to a locally made clay pot with a lid, which utilizes evaporative cooling to refrigerate the water. Therefore, a total number of 83% of the user HHs cover their final storage container to prevent recontamination. The user HHs clean the clay pots regularly with 50% reporting cleaning daily and 50% approximately every three days.

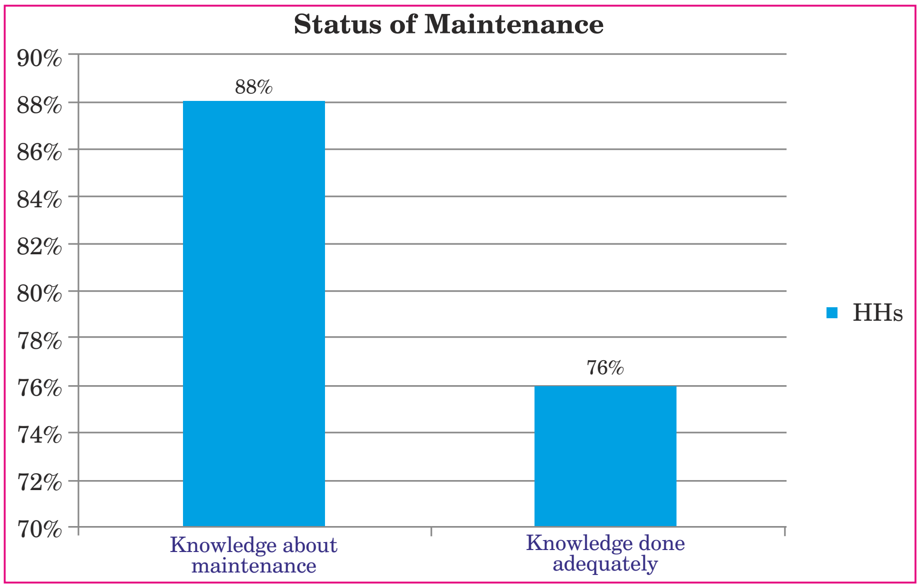
Maintenance

The flow rate through the filters slows down over time as the pores' openings between the sand grains become clogged. For turbidity levels greater than 50 NTU (Nephelometric Turbidity Units), the water should first be strained through a cloth or sediment before using the BSF.

When the flow rate drops to a level that is inadequate for the HH use, the filter needs to be cleaned. This is done by a simple 'swirl and dump' procedure performed on the top of the sand, and only takes a few minutes. The swirl and dump process consists of agitating the surface sand, thereby suspending captured material in the standing layer of the water. The contaminated water will then be removed and dumped away. The process can be repeated as many times as necessary to regain the desired flow rate. The need for cleaning depends on the amount and quality of water being put through the filter. If the water is relatively clean (turbidity less than 30 NTU), the filter can likely run for several months without this maintenance procedure. When a BSF is used for the first time, there is no biofilm yet. The biological layer typically takes 20 to 30 days to develop to maturity in a new filter depending on inflowing water quality and usage, removal efficiency and the subsequent effectiveness of the filter increase throughout this period. After cleaning, a re-establishment of the biological layer takes 2-3 weeks' time.

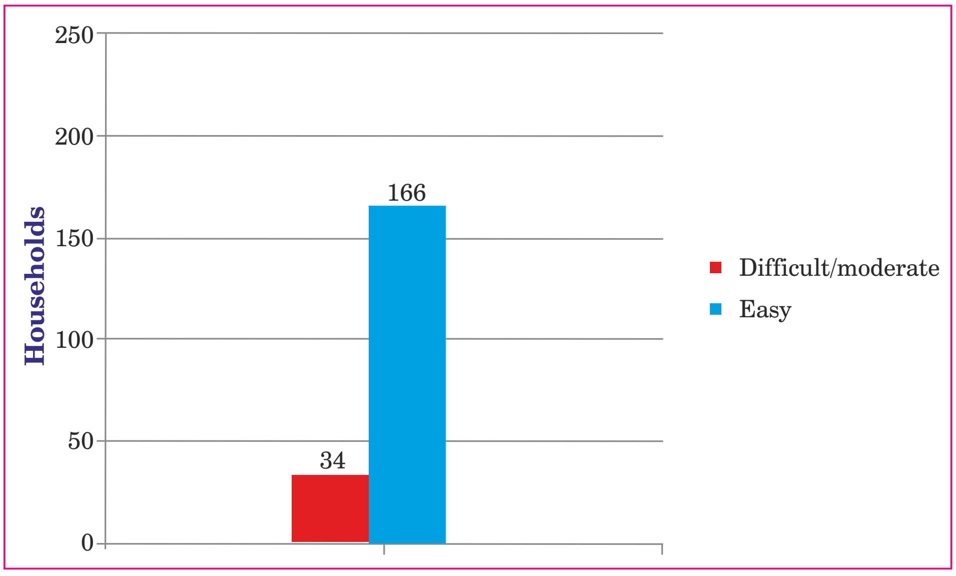
According to the study findings, around 82% of the user HHs had maintained their BSF using the swirl-and-dump method since installation regularly. On demonstration and discussions about maintenance techniques, 76% found to be practicing it in the correct manner. The maintenance frequency varied with bimonthly, quarterly and on half yearly basis; however 9% reported that they do it according to decreased flow rate of water from the filter. From the outset, it appears that at some places the maintenance is being performed more frequently than necessary.

Graph 8 - Status of maintenance of BSFs



Though 14% of the BSFs were not being maintained and the reasons for that were - their flow rates were still sufficient for their HH needs, lack of knowledge about correct maneuver and ignorance of the need are also causes. Among the user HHs which had performed the maintenance, 86% reported that it was easy, and 14% said that it was a moderate task. All user HHs stated that the flow rate increased afterwards.

Graph 9 - Ease of operation and maintenance



The user HHs that inadequately performed maintenance were given a demonstration after the interview so that they would be encouraged to do so in the future when the flow rate drops to an unacceptable level.

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2.5 Quality of water

Water quality is a term that is used to describe the cleanliness of water to a degree that is required for maintaining and protecting human health. Therefore, ideally, water consumed by human beings should be free from all forms of chemical and biological contaminations.

According to 59% of the respondents, the water from the naadis is muddy, while 87% of the people reported that the naadi water stinks due to improper management of naadis itself and because of an overall lack of cleanliness. Water from tube-wells is reported to be brackish, saline in taste, sometimes with pungent smell and causes certain gastric complaints like burping, indigestion and constipation, as per the respondents.

According to the study findings, 96% of the respondents found that the filtered water from BSFs does not look muddy in appearance as before, and the sparkling clear water was odourless ("water tastes and looks good", as reported).

The user HHs also noted that the water tastes like pipe-supply water that is made available in cities by the government after required treatment etc.). Three questions in the survey-interview addressed this issue by asking the user HHs to give their preferences for taste, colour and odour when comparing the source and filtered water. As another indicator of user acceptance, 100% of the user HHs said they preferred the filtered water over the raw water for all three categories.

Water for health

In village Hopardi, people are gradually ignoring traditional water resources and are becoming dependent on groundwater (tube-wells). This has resulted in the installation of a large number of tube wells throughout the village. The Over exploitation of ground water has led to depletion in its level with increased fluoride content.

Nathi Devi a resident of this village said that their generation survived on surface water but the upcoming generation uses ground water only. This water causes health problems

like stomach ache, vomiting, indigestion, constipation etc.

According to her, the health problems in her family have reduced to a great extent ever since they started using filtered water. Prior to this children suffered with one or the other health problem and doctors were to be visited frequently. Now it is not so.

Nathi Devi made us taste filtered and unfiltered water and said that the use of filter has improved the taste of water. She said that the fresh filtered water saves time and fuel as pulses and vegetable take less time to get cooked. Nearby 1/3 time is saved. She said with a smile that just as cooking gets faster in filtered water, similarly food gets digested rapidly in the stomach and indigestion is prevented. Bio Sand Water filter has proved to be a great asset.

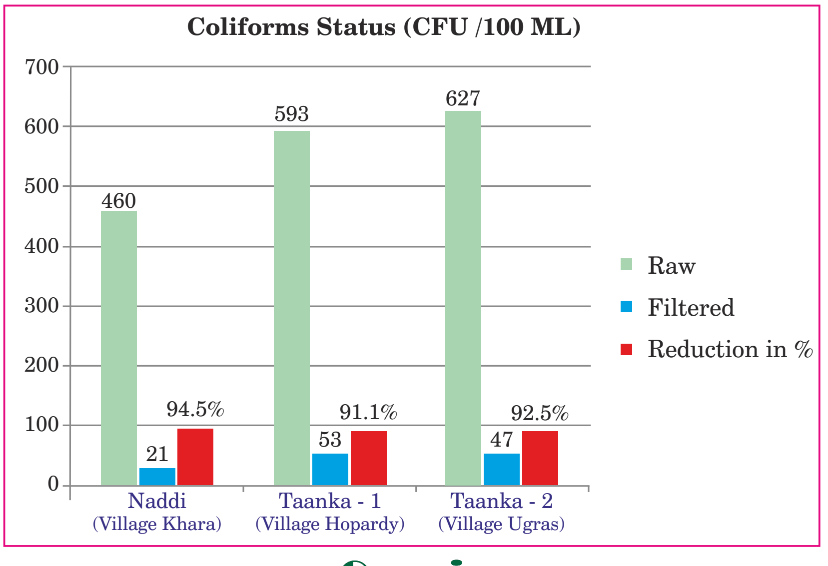
Water quality tests results

According to Center for Affordable Water and Sanitation Technologies (CAWST), The BSF removes pathogens such as bacteria, protozoa and helminths from water. BSFs are also somewhat effective for the removal of some viruses. Physical and chemical parameters such as turbidity and iron are also addressed by BSFs. However, dissolved chemicals (such as organic pesticides or arsenic) are not removed by the filters. The treated water generally has an acceptable colour, taste and odour. The table below shows the BSF treatment efficiency in removing pathogens and turbidity and the laboratory results clearly show that pathogens like coliform bacteria were removed to a significant extent.

	Bacteria	Viruses	Protozoa	Turbidity
Laboratory	Up to 96.5%	70 to >99%	>99.9%	95%

With a view to objectively analyse the impact of BSFs on the properties of water, scientific tests were undertaken. In this process, one influent and one effluent sample each were collected from three BSFs in October, 2017. Total coliforms, fecal coliforms, and total heterotrophic bacteria were measured and are presented in the table below:

Graph 10 - Reduction in Coliforms Status per 100 ML



At the point of testing, the three BSFs had been in operation for almost 6 months, and had an average flow rate of 0.75 L/min. There was an average of 77% removal of total coliforms and a 93 -96% removal of fecal coliforms when measured. So the filters have an average 90.95% removal range of fecal coliforms as also described in the BSF literature.

The chemical test reports of groundwater from tube-wells revealed that water in the study area contains impurities like fluoride and other dissolved salts that brings salinity to it. According to the community members, salinity has affected most of the tube-wells in study villages. This water contains elements like fluoride in higher limits than prescribed, which is a serious health hazard.

Easy to use filters

In village Sanwreej, Sohani (38) showed filtered and unfiltered naadi's water with a great pride. When asked about the effect of filtration she readily said that it is explicit that the sparkling water is the filtered one, whereas the muddy water is from the naadi.

She said that earlier when they used unfiltered water, they had to face many health problems. Children suffered the most. They often complained about stomach-ache and had to undergo anti worm medication.

But now she said none of her three children complains about any stomach disorder. Sohani's mother-in-law said that the use of filtered water has relived them from the problem of indigestion. When asked about how she is maintaining the BSF, she stated that she learned the skill of cleaning BSF during training and its very simple process just by using the swirl and dump technique. Once it's cleaned, the BSFs are refilled with new water and it produces the same filtered water with same taste. "Never thought that water could be cleaned without any cost", she smilingly concluded.

2.6 Impact on Health

Water is an essential need for human body and is very important for metabolism. Unsafe, contaminated water leads to a number of waterborne diseases. The term waterborne diseases refers to a group of health conditions that arise through contact with or the consumption of contaminated water. Water may contain biological as well as chemical contamination which affects the human health adversely. Chemical contamination often is a cause of chronic diseases such as fluorosis.

Biological contamination caused by pathogenic micro-organisms is most commonly present in water. Pathogens causing infections are various bacterial, viral or protozoal micro-organisms. The main causes behind this are improper water treatment, contaminated water at source, poor sanitation, unhygienic conditions and contact with animals. World Health Organization (WHO) estimates 88% of diarrheal disease is due to unsafe water supply, inadequate sanitation and hygiene. Chemical contamination also affects the health adversely and the impact on the health may be visible after a long term use of contaminated water. Most common chemical contaminants are fluoride, nitrites, arsenic, etc, which may be present in higher concentration than permissible limits.

Waterborne diseases may lead to gastrointestinal disorders, skin diseases, ear and eye problems and sometimes dental and skeletal deformities. The most common waterborne diseases in the study area are reported to be gastrointestinal disorders, cholera, typhoid, and hepatitis and worm infestations. Diarrhea is the predominant symptom of many diseases, which can cause dehydration and even mortality in untreated, complicated cases. Unsafe drinking water is also the main sources of acute gastrointestinal. Depleting ground water level is also a threat and the main cause of increasing levels of chemical contamination in water. Longer use of chemically contaminated water results in various kinds of diseases depending upon the substance present in higher concentration.

User HHs reported that prior to the use of BSFs, the common waterborne diseases or complaints in the area were diarrhea, jaundice, hepatitis (liver infections), cholera, typhoid, abdominal ache and worms infection. These reportedly affected about 87% of the children of 0 to 8 years of age and about 56% of the adults.

Shushila advocates for filters

Shushila Bishnoi, a 35 years old homemaker from Shivpura village is happy that no one in her family have health issues such as stomach ache, indigestion, constipation and recurring vomiting. She attributes this change to the bio sand filter that was installed at her home with support from GRAVIS.

She said, "All villagers are dependent for their water related needs on naadi in the nearby village because the underground water in this area is highly saline and not consumable. Although all of us take care of this naadi, given that it is an open rainwater harvesting structure, the cleanliness is a major concern. Water gets dirty because of various reasons such as sandy wind, trash and other pollutants in surroundings. Earlier we all had no choice but to drink that water after filtering it with a cloth but water was still not very clean and all of used to fall sick very often. I lost my husband to continuous diarrhea and vomiting. This happened due to polluted water."

When water is stagnant in the naadi for too many days, problems arise frequently and generally children suffer a lot from stomach-ache and diarrhea.

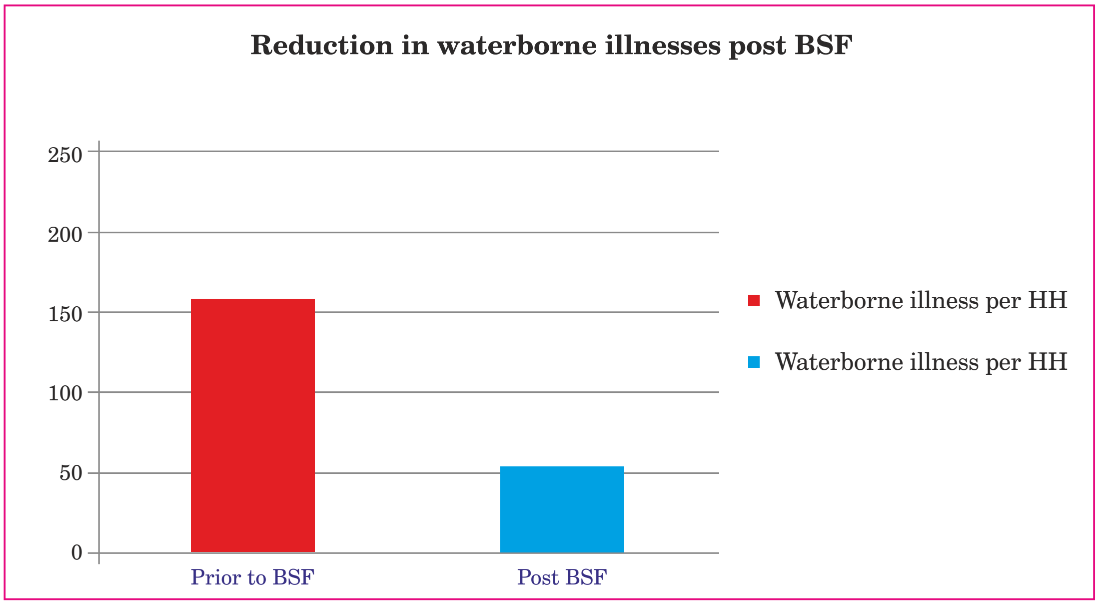
"But now situation has changed, after we got to a precious gift from GRAVIS in the form of BSF. After using filtered water we got significant change in our life. There is a steady decrease in the occurrence of stomach related ailments and infections. In fact we are saving money that we used to spend to address various health related expenses – travel to hospital, treatment and medicines etc."

Sushila says that she and her family have realized the importance of having a biosand filter at home but only after having lost a life. She has now become an ambassador of bio sand filters in the village and is popularizing its use and installation. She is also motivating people to drink water only from BSFs. She believes that people will lead a much healthier and happier life if they have BSFs at their homes and they drink water purified by it.

The primary goal of this study did not include performing a very comprehensive health impact analysis on BSFs. However, the study did have a health analysis component to measure difference/change on users' health status over the period of the study, as a result of using BSFs. Both quantitative and qualitative questions were asked in order to determine if the users felt an improvement in their health as a result of consuming filtered water.

The user HHs were asked to estimate how many cases of waterborne disease were reported in each age category prior to using BSFs and afterwards. In the study, we estimated the incidence of waterborne diseases cases for the 200 HHs – broken down by age category – before (Pre – BSF) and after (Post – BSF) the installation of the BSFs. The survey results suggest that 157 HHs reporting waterborne disease (at least one HH member) prior to using BSFs and about 52 reporting waterborne disease (at least one HH member) after using BSFs, which is a 66% reduction in the occurence of waterborne diseases.

Graph 11 - Reduction in occurrence of waterborne diseases



Graph 11, above, indicates that the use of BSFs has contributed to a 66% reduction in the occurrence of waterborne diseases. Not only the water quality tests results showed that the BSFs reduced bacterial concentrations, but the incidence rate of waterborne diseases also appears to have lowered down, which is very significant for a rural area in the Thar Desert where sanitation and hygiene situation and health services and facilities is still quite poor. Certain biases that could have affected the health survey include the lack of clarity on definition and understanding of waterborne diseases, unawareness of the true number of cases in the HH on the part of the family head or the main respondent and lack of memory. In study villages, waterborne diseases reported to be quite common, especially in children due to living conditions that lack safe drinking water, have poor sanitation facilities and lack good hygiene practices.

The user's views and consultation with a physician indicate a definite, positive impact of BSFs on the overall health status of users with reported reduction in the incidence of waterborne diseases.

CHAPTER 3 : RECOMMENDATIONS AND CONCLUSION

Major Findings

- Based upon the results from the study objectives, the use of BSFs has been found to be a successful water treatment technology, and proves an easily practicing option for the Thar Desert communities in India. This is evident from the information gathered from the beneficiaries of 200 BSFs installed in the study area.
- All HHs responded that the filter is strong and durable, a technology they would buy in the market if it was available. It provides a sufficient flow rate, provides colourless, odourless water with better taste, than the source. The filter improves the health of their family, noted by beneficiaries.
- To develop user comprehension of the filter, education about safe water, operation and maintenance of the filter was given in August 2016 through PPI-GRAVIS project. Approximately two months later, 100% of the HHs reported that the BSF is easy to use, they used it frequently, and that they washed their collection container on a regular basis. A total of 88% of the HHs reported covering their containers to prevent recontamination of the filtered water.
- Study findings suggest that prior to the use of BSFs the commonly found waterborne health conditions in the study area were diarrhea, jaundice, hepatitis (liver infections), cholera, typhoid, abdominal ache and worms infections. These affected about 87% of the children of 0 to 8 years and 56% of the adults. Health impact data shows the reduction of 65% to 67% of waterborne diseases among all age groups, reported by the beneficiaries.
- A component on hygiene and sanitation education has helped to reduce the incidence of waterborne diseases, especially in vulnerable groups like children under five years of age and in the elderly.
- A frequent monitoring of BSFs' use was conducted through follow-up visits. It was found that 100% of the beneficiaries were using it on a regular basis and 86% of the users conducted the maintenance of BSFs efficiently.
- The issue of collection and storage is an area that needs to be improved. Unfortunately, bleach or chorine solution is not available locally to disinfect the filtered water and to reduce the risk of recontamination in the stored water. Therefore, the participating HHs need to understand the importance of cleaning the containers and of covering their stored water.
- Given the sustainable nature and environment friendly nature of the practice, rainwater needs to be tapped to its fullest potential as the primary water source and construction of rainwater harvesting structures should be supported and encouraged. The fact that BSFs are most effective with the fresh water makes it all the more important.

Recommendations

Along with these conclusions, the experience gained from this study provides the basis for many recommendations for future work and research with the BSFs.

- All community members in Thar Desert should get opportunity/orientation to purchase/procure a BSF at an affordable cost which are easily available locally.
- Only a limited number of filters were available/supported by PPI, USA-GRAVIS project. There is a need of expanding the coverage of BSFs.
- There is an opportunity of assembling more BSFs locally in the form of a micro-enterprise led by local CBOs, with training and facilitation from GRAVIS and other organizations.
- Utilizing more interactive health education and visual aids would help to increase the users' understanding.
- BSF users must be oriented that rainwater is purified the best through filters and hence they must use water from rainwater bodies to be filtered. Chemical contamination from groundwater is difficult for the BSFs to remove.
- The community members, who did not receive a BSF, should also be included in the orientations conducted on the importance of safe water practices along with the use and maintenance of the BSF, in an efficient and comprehensive manner as a forward , hoping they would have filters sometime in future.
- The tests conducted on water were from limited resources. If it would have been done with a greater number of resources, more accurate information would have been gathered.
- The construction/assembling of BSF is a skilled work. GRAVIS can impart skills among the women of Self Help Groups (SHGs) or among youths too. In the future, it may be good income generating activity for local revenue while also helping BSF penetrate in the remote rural areas.
- The BSF may be introduced in urban areas/slums also because the water of BSF is definitely safer than other locally used filtration methods. It needs to be acknowledged that slum populations in cities and small towns also live with unsafe drinking water

APPENDIX - 1

MAIN SOURCE OF DRINKING WATER 2001-2011 [19]

TOTAL																	
State Code	India/State/ Union Territory#	Total Households		Tap Water		Well Water		Handpump /Tubewell water		Other Sources of water		New Question in 2011				India / State / Union Territory#	State Code
												Tap		Well			
		2011	2001	2011	2001	2011	2001	2011	2001	2011	2001	Treated	Un-treated	Covered	Un-covered		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	2	1
00	INDIA	246,692,667	191,963,935	43.5	36.7	11.0	18.2	42.0	41.2	3.5	3.9	32.0	11.6	1.6	9.4	INDIA	00
01	Jammu & Kashmir	2,015,088	1,155,768	63.5	52.5	6.5	5.6	12.8	12.7	16.7	29.2	34.7	29.2	1.9	4.7	Jammu & Kashmir	01
02	Himachal Pradesh	1,476,581	1,240,633	89.5	84.1	2.9	4.8	4.2	4.5	3.4	6.6	83.9	5.6	1.5	1.3	Himachal Pradesh	02
03	Punjab	5,409,699	4,265,156	51.0	33.6	0.4	0.8	46.6	64.0	2.0	1.6	41.1	9.9	0.2	0.2	Punjab	03
04	Chandigarh#	235,061	201,878	96.7	91.9	0.1	0.0	2.6	8.0	0.6	0.2	93.7	3.0	0.1	0.0	#Chandigarh	04
05	Uttarakhand	1,997,068	1,586,321	68.2	65.9	1.1	1.2	24.0	20.8	6.7	12.1	53.9	14.3	0.7	0.4	Uttarakhand	05
06	Haryana	4,717,954	3,529,642	68.8	48.1	..0	11.7	25.0	37.9	3.2	2.2	55.9	12.9	0.7	2.3	Haryana	06
07	NCT of Delhi#	3,340,538	2,554,149	81.3	75.3	0.1	0.0	13.7	21.9	4.9	2.7	75.2	6.1	0.1	0.0	#NCT of Delhi	07
08	Rajasthan	12,581,303	9,342,294	40.6	35.3	10.8	24.0	37.5	32.9	11.1	7.9	32.0	8.5	1.2	9.6	Rajasthan	08
09	Uttar Pradesh	32,924,266	25,760,601	27.3	23.7	4.0	11.6	67.9	64.1	0.9	0.6	20.2	7.1	0.6	3.4	Uttar Pradesh	09
10	Bihar	18,940,629,	13,982,590	4.4	3.7	4.3	12.6	89.6	82.9	1.7	0.8	3.1	1.3	0.7	3.7	Bihar	10
11	Sikkim	128,131	104,738	85.3	70.3	0.6	0.1	0.1	0.4	14.1	29.1	29.2	56.1	0.4	0.2	Sikkim	11
12	Arunachal Pradesh	261,614	212,615	65.5	67.8	5.7	4.7	13.1	9.7	15.7	17.8	26.4	39.1	1.4	4.3	Arunachal Pradesh	12
13	Nagaland	399,965	332,050	47.2	42.0	25.7	34.9	6.7	4.5	20.5	18.6	6.1	41.1	6.6	19.1	Nagaland	13
14	Manipur	507,152	397,656	38.6	29.3	7.5	6.4	6.8	7.7	47.1	56.6	25.6	13.0	2.8	4.7	Manipur	14
15	Mizoram	221,077	160,966	58.7	31.9	4.7	2.0	1.7	4.0	34.9	62.0	39.4	19.3	2.0	2.7	Mizoram	15
16	Tripura	842,781	662,023	33.2	24.6	27.4	38.3	34.3	27.9	5.1	9.1	20.3	12.9	2.9	24.5	Tripura	16
17	Meghalaya	538,299	420,246	39.3	34.5	25.4	27.4	5.4	4.4	29.9	33.7	27.8	11.5	6.9	18.4	Meghalaya	17
18	Assam	6,367,295	4,935,358	10.5	9.2	18.9	26.7	59.4	49.6	11.3	14.6	9.2	1.3	1.7	17.2	Assam	18
19	West Bengal	20,067,299	15,715,915	25.4	21.4	6.0	10.0	66.8	67.1	1.7	1.5	21.0	4.4	0.7	5.4	West Bengal	19
20	Jharkhand	6,181,607	4,862,590	12.9	12.6	36.5	51.8	47.3	30.1	3.4	5.6	10.0	2.9	1.9	34.6	Jharkhand	20
21	Odisha	9,661,085	7,870,127	13.8	8.7	19.5	28.6	61.4	55.5	5.2	7.3	10.0	3.9	2.2	17.3	Odisha	21
22	Chhattisgarh	5,622,850	4,148,518	20.7	15.5	11.4	24.6	65.6	55.0	2.3	4.9	12.3	8.4	0.8	10.6	Chhattisgarh	22
23	Madhya Pradesh	14,967,597	10,919,653	23.4	25.3	20.0	29.0	54.6	43.1	2.0	2.6	16.4	6.9	1.1	18.9	Madhya Pradesh	23
24	Gujarat	12,181,718	9,643,989	69.0	62.3	7.1	11.7	21.2	21.8	2.7	4.2	39.8	29.2	2.3	4.8	Gujarat	24
25	Daman & Diu#	60,381	34,342	75.2	72.9	0.7	3.4	23.5	23.4	0.5	0.2	54.6	20.6	0.5	0.2	#Daman & Diu	25
26	D & N Haveli#	73,063	43,973	46.5	28.2	7.2	19.4	45.0	48.8	1.3	3.6	26.0	20.5	1.4	5.7	#D & N Haveli	26
27	Maharashtra	23,830,580	19,063,149	67.9	64.0	14.4	17.8	15.5	15.8	2.1	2.4	56.3	11.6	2.2	12.2	Maharashtra	27
28	Andhra Pradesh	21,024,534	16,849,857	69.9	48.1	6.4	16.5	20.6	32.0	3.1	3.4	49.0	20.9	0.5	5.9	Andhra Pradesh	28
29	Karnataka	13,179,911	10,232,133	66.1	58.9	9.0	12.4	21.5	25.7	3.5	3.0	41.2	24.8	1.0	8.0	Karnataka	29
30	Goa	322,813	279,216	85.4	69.0	11.1	26.1	0.3	1.1	3.2	3.8	82.0	3.4	4.0	7.1	Goa	30
31	Lakshadweep#	10,703	9,240	20.3	3.1	71.7	93.0	2.5	1.6	5.5	2.4	9.1	11.1	6.9	64.9	#Lakshadweep	31
32	Kerala	7,716,370	6,959,206	29.3	20.4	62.0	71.9	4.2	3.0	4.4	4.8	23.4	6.0	14.6	47.4	Kerala	32
33	Tamil Nadu	18,493,003	14,173,626	79.8	62.5	5.1	10.6	12.8	23.0	2.4	3.8	55.8	23.9	1.2	3.8	Tamil Nadu	33
34	Puducherry#	301,276	208,655	95.3	89.3	1.9	2.7	2.5	6.6	0.3	1.4	90.8	4.5	0.1	1.8	#Puducherry	34
35	A & N Island#	93,376	73,062	85.0	76.2	7.3	16.0	0.5	0.5	7.1		68.8	16.2	0.7	6.6	#A & N Island	35

[19] http://censusindia.gov.in/2011census/hlo/Data_sheet/India/Drinking_Water.pdf

APPENDIX - 2

About Bio Sand Filters

BSF technology

BSF is a sustainable and proven drinking water purification method. It reduces the leading causes of waterborne disease and death. BSF remove pathogens and suspended solids from water using biological and physical processes that take place in a sand column covered with a bio film. BSFs have been shown to remove heavy metals, turbidity, bacteria, viruses and protozoa. BSFs also reduce discolouration, odour and an unpleasant taste. It can also be used for arsenic removal through simple adaptation. 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 it works under the force of gravity without using of any form of energy or on line pressure.[20]

History

The household BSF was proposed by Dr. David Manz in the late 1980s at the University of Calgary, Canada. The system was developed from the slow sand filter, a technology that has been used for drinking water purification since the 1800s. Initial lab and field tests were conducted in 1991; the system was patented in 1993 and was implemented in the field in Nicaragua. The Canadian non-profit company Center for Affordable Water and Sanitation Technology(CAWST) was co-founded in 2001 by David Manz and Camille Dow Baker to promote education and training in water purification and sanitation including using this technology, and to continue developing it. A privately owned company, Hydraid Bio sand Water Filter produces and distributes plans for filters.

Components and process of BSF

Dr. David Manz, described the process of filtration that 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 under drain (coarse rock). Water is pooled to a depth on top of sand, and it flows downward under gravity into the under drain 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 electro statically 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.

[20] Lalit Mohan Sharma1 , Saurabh Sood2, Reinventing the Biosand Filter: An Easy Solution for Safe Drinking Water. http://www.smsfoundation.org/wp-content/uploads/2016/02/Reinventing-the-biosand-filter.pdf

Remaining microbes are unable to survive in the lower section of the filtering medium that has anaerobic conditions, devoid of oxygen and light.

Remaining microbes are unable to survive in the lower section of the filtering medium that has anaerobic conditions, devoid of oxygen and light.

During the run

The high water level (hydraulic head) in the inlet reservoir zone pushes the water through the diffuser and filter, and then decreases as water flows evenly through the sand. The flow rate slows because there is less pressure to force the water through the filter. The inlet water contains dissolved oxygen, nutrients and contaminants. It provides the oxygen required by the microorganisms in the biofilm. Large suspended particles and pathogens are trapped in the top of the sand and partially plug the pore spaces between the sand grains. This causes the flow rate to decrease.

Pause period (idle time)

Idle time typically comprises greater than 80% of the daily cycle; during this time, microbial attenuation processes are likely to be significant. Most removal occurs where water is in contact with the biofilm. The processes that occur in the biofilm have not been identified. When the standing water layer reaches the level of outlet tube, the flow stops. Ideally, this should be high enough to keep the biofilm in the sand layer wet and allow oxygen to diffuse through the standing water to the biolayer. The pause period allows microorganisms in the biolayer to consume the pathogens and nutrients in the water. The rate of flow through the filter is restored as they are consumed. If the pause period is too long, the biolayer will consume all of the pathogens and nutrients, and will die, reducing the efficiency of the filter when it is used again. The pause period should be between 1 and 48 hours. Pathogens in the non-biological zone die from a lack of nutrients and oxygen.[21]

It is an appropriate technology for developing countries. People directly attribute their improved health and the better taste of the water to use of the BSF.

[21] https://en.wikipedia.org/wiki/Biosand_filter

ACRONYMS

BSF	Bio Sand Filter
CBO	Community Based Organization
CAWST	Center For Affordable Water and Sanitation Technology
DDT	Dichloro-Diphenyl-Trichloroethane
FGD	Focus Group Discussions
GRAVIS	Gramin Vikas Vigyan Samiti
HHs	House Holds
NaDCC	Sodium Dichloroisocyanurate
NCAER	National Council For Applied Economic Research
NGO	Non-governmental Organization
NRDWM	National Rural Drinking Water Mission
NSSO	National Sample Survey Organization
OBC	Other backward Class
PHED	Public Health Engineering Department
PPM	Parts Per Million
PPI, USA	People for Progress in India, United Stated of America
RGI	Registrar General Of India
SC	Schedule Caste
ST	Schedule Tribe
SODIS	Solar Disinfection
TDS	Total Dissolved Solids
UN	United Nations
VDC	Village Development Committee
WHO	World Health Organization
WASH	Water Sanitation and Hygiene

GLOSSARY

Beris	Percolation Well
Bigha	Measure of Land(6.25 Bigha = 1 Hectare)
Fitkari	Alum
Gram Panchayat Bhawan	Village Community Hall
Jhalra	Seepage Water at Downstairs
Lal Dava	Potassium Permanganate
Matka	Earthen Pot
Naadis	Village Pond
Panchayat	An Administrative Unit Comprising of a few Revenue Villages
Taankas	Rainwater Harvesting Structure
Taanklis	Small Rain Water Harvesting Structure

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Gramin Vikas Vigyan Samiti (GRAVIS) or Center of People's Science for Rural Development is a non-governmental, voluntary organization that takes a Gandhian approach to rural development by working with the poor communities to enable them to help themselves. Since its inception in 1983, GRAVIS has worked with over 60,000 desert families across over 1300 villages in India reaching a population of over 1.3 million, and has established over 2,900 Community Based Organizations (CBOs). Through its dedicated field work, as well as its research and publications, GRAVIS has come to occupy a leading position amongst the voluntary organizations in India.

Gravis

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