Expanding Adoption of Drinking Water Treatment Systems in Developing Countries: A Case Study from Tamil Nadu, India

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Abstract: Household-level water treatment and safe storage systems (HWTS) are simple, local, user-friendly, and low cost options to improve drinking water quality at the point of use. However, despite conclusive evidence of the health and economic benefits of HWTS, and extensive promotion efforts in over 50 countries in the past 20 years, implementation outcomes have been slow, reaching only 15-20 million regular users. This study attempts to understand the barriers and drivers affecting HWTS implementation. Using a case study example of a biosand filter program in southern India, system dynamics modelling is shown to be a useful tool to map the inter-relationships of different critical factors and to understand the dissemination dynamics. It is found that long-term funding is needed for project success, and the twin goals of expanding quickly and achieving financial sustainability appear to be difficult to achieve simultaneously under the current program structure.

Keywords: developing countries, household water treatment systems, innovation diffusion, sustainable development, system dynamics modelling.

INTRODUCTION

Traditionally, access to drinking water in the developing countries has been mostly provided for by central-level, municipal or community water supply schemes such as piped water systems with public stand posts on the street, protected dug-wells or bore-wells, and protected springs. Although these schemes have reliably served hundreds of millions of people, centralized schemes have certain limitations when implemented in rural regions. They include high per capita construction cost, potential poor water quality from re-contamination during transport and storage, and the lack of resources and capacities to properly operate and maintain the water supply infrastructure (Sobsey, 2002; Nath et al., 2006).

Since the 1980s, household-level water treatment and safe storage systems (HWTS) have been developed and promoted by the scientific community and health authorities as alternatives to centralized schemes. HWTS are usually simple, local, user-friendly, low cost, and have been proven to reduce diarrhoeal diseases. A variety of HWTS methods exist, but some of the most common treatment practices include household chlorination, solar disinfection, ceramic filters, biosand filters, and flocculationdisinfection. Treated water is then stored safely to prevent re-contamination, for example, using containers with narrow openings and dispensing devices such as taps or spigots (Sobsey, 2002; WHO/UNICEF, 2005).

However, despite evidence (Clasen and Cairncross, 2004; Fewtrell et al., 2005; Nath et al., 2006) of the health and economic benefits of HWTS, and the promotion efforts by development agencies and governments in over 50 countries in the past 20 years, implementation outcomes have been slow. It is estimated only 15-20 million people uses HWTS on a regular basis, and the long-term sustained use is often low (Murcott, 2006; Luby et al., 2008). While a few small local initiatives show promising results, there is not yet any successful extensive implementation (Lantagne et al., 2006).

RESEARCH OBJECTIVES

This study attempts to identify and investigate the critical factors, barriers, and solutions to the introduction, adoption, scale up, and sustained use of HWTS practices in developing countries..

METHODS

This study consists of 5 phases. In the first phase (Apr 06 – Aug 07), literature on water and sanitation, HWTS implementation, and theories of innovation diffusion were reviewed. Many potential critical factors affecting the dissemination of HWTS were identified. System dynamics modelling was selected as an integrating and simplifying analytical tool to clarify the complex situation. Case studies on three non-profit organizations (in Nepal, India, and Ghana) were selected to evaluate the usefulness of system dynamics to assist the identification of leverage policy interventions to scale-up household water treatment implementation sustainably.

In the second phase (Sep 07 – Apr 08), the author visited DHAN Foundation (Development for Human Action) in Madurai, India; ENPHO (Environment and Public Health Organization) in Kathmandu, Nepal; and Pure Home Water in Tamale, Ghana, to learn about their household water treatment promotion programs. Extensive personal and group interviews were conducted to a variety of stakeholders, including project management staff, community workers, partner organizations staff, government officials, donors representatives, shopkeepers, and households end-users. The main goal of this first visit was to collect information necessary to formulate draft system dynamics models to describe the HWTS dissemination process. Appropriate quantitative and qualitative research methods such as data triangulation, standardized data recording format, thick description, and interviewee confirmation were employed to ensure the accuracy and representativeness of the information (Flick, 2006).

In the third phase (May 08 to Dec 08), the individual interview results from India were converted into partial system dynamic models. These partial models were compared and combined to form an overall integrated model that could tell a logical and compelling story on the dissemination process. Decision rules were specified based on common-sense. In many cases, popular and proven decision rules and formulations from existing system dynamics literature were borrowed and applied to the India model.

The model was subjected to various checks, such as dimensional consistency, partial model testing, and extreme conditions testing to ensure quality. Models for Nepal and Ghana were formulated according to the same process.

In the fourth phase (Jan 09 to present on-going), the author re-visited India and Ghana for model validation and calibration. The draft models developed from phase 3 were shown to the project staff for comments and modifications, particularly in the areas of logical structure, decision rules and relationships, reference mode and behaviour, and calibration to historical data. The model validation activities were very much iterative, consisted of showing the updated model to project staff, obtaining feedbacks, collecting more information, modifying the models, running sensitivity analysis and logical checks, and showing the model to project staff again. Before leaving India and Ghana, the project staffs were satisfied the story that the final models were conveying.

In the fifth phase (until Dec 09), the final models for these 3 case studies will be used to simulate HWTS adoption rates under different potential intervention policies. Some policies may involve simply changing model parameter values (e.g. double the marketing budget, offer a 50% subsidy), while some policies may modify model structures (e.g. create information link from water quality testing authorities to villagers). The simulated behaviour of each of these intervention strategies will be compared to evaluate their effectiveness. Finally, comparisons of different models and their respective policy implications may yield further insight into whether HWTS dissemination processes are regionally specific, or can be generalized for worldwide application.

This rest of this paper will discuss the preliminary findings on the India model. The analysis for Ghana and Nepal are still ongoing.

BIOSAND FILTER PROGRAM IN TAMIL NADU, INDIA

Development of Human Action (DHAN) Foundation, a professional development organization, was established in October 1997. It is headquartered in the city of Madurai, in a southern state of Tamil Nadu, India. As of March 2008, about 650,000 families in 11 states are direct beneficiaries of DHAN's programs, served from the 130 field offices. Over 600 professional and programme staff, as well as over 2300 community workers (also referred to as *field associates*) work for DHAN (DHAN Foundation Annual Report, 2008).

To function effectively as a large organization, DHAN's activities are decentralized into 6 programmes, under the coordination of the main central office. Activities related to drinking water and sanitation is managed under the *Vayalagam* programme.

In 2004, DHAN obtained professional training from a Canadian non-profit engineering consultant on the construction of the BioSand Filter (BSF). DHAN believed that the BSF is an excellent technology to provide safe drinking water to rural households.

A biosand filter consists of a concrete box that is filled with layers of sand and gravel. A biological layer (often called a biolayer) of slime, sediment and microorganisms develops at the sand surface. To use the filter, water is simply poured through the top and collected in another storage container at the base of the spout. Water slowly passes through the biolayer, sand and gravel. Pathogens and suspended material are removed through various physical and biological processes that occur in the biolayer and sand. Figure 1 shows a schematic diagram of the structure of a BSF.

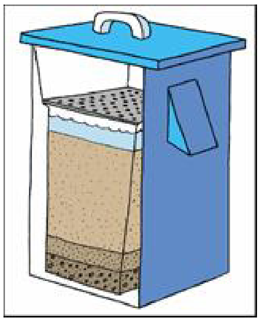


Figure 1 – Structure of a Biosand Filter

The biosand filter has been tested by various government, research, health institutions, and non-governmental agencies in both laboratory and field settings. Overall, these studies have shown that the biosand filter can generally reduce pathogens by 90+% and diarrhea incidence by 30-40%. The main advantages of the BSF are low construction cost and no reoccurring running cost. The BSF is made with locally available materials, is durable and function, is simple and easy to use. The main disadvantages are its heavy weight, and it may not be effective if the raw water is highly turbid.

Figure 2 – DHAN's BSF in a household

In January 2005, DHAN started its first BSF implementation project, funded by the Canadian High Commission in New Delhi. Because the BSF was a relatively new initiative at DHAN, in order to increase its chance of success, the BSF program was mostly implemented in districts where DHAN has long, established presence. Since then, additional funds from other donors were granted to DHAN to further promote the BSF. Figure 2 shows a BSF in use at a rural household.

As of December 2008, a total of 2690 filters have been distributed in 88 villages in 25 districts. Number of households covered under the BSF program (i.e. BSF is available in the local area) is estimated to be 15,000. The dissemination process typically follows this order:

1. Identify suitable implementation sites
2. Train local field associates on water, health, treatment options, and BSF
3. Generate awareness in villagers through educational workshops
4. Collect purchase demand from households
5. Construct, deliver, and install filters
6. Train new users on proper operation and maintenance procedure
7. Monitor and follow-up filter households

The production, transportation and installation cost per BSF was about 1000 Indian Rupees (INRs) in 2005, and increased to about 1300 INRs by 2009 (about US$ 25-30). In 2005, filter receiving households were asked to pay 50 INRs in cash. This subsidy was reduced in 2006, and households have had to pay 300 INRs since.

Some of the apparent challenges encountered in the BSF program include high required subsidy, large number of households discontinued using their purchased BSF, and increasing number of broken filters.

MODEL REPRESENTATION

The overall model describing DHAN's BSF program was developed for a 240-months (20-years) time span from January 2005 until December 2024. Inflation and income growth during this time span is assumed to be the same as the average in the past 15 years, i.e. inflation = 7%/year; income growth = 11%/year. (Government of India Labour bureau, 2009). The model consists of 9 sub-models. Simplified versions of these sub-models are shown in this paper.

<u>Sub-model #1: Budget allocation (Figure 3)</u>

Expenses on DHAN's BSF program can be divided into 6 categories as shown in Figure 3. Actual values (in INRs/month) from January 05 to January 09 are inputted into the model exogenously. Different future funding scenarios are considered in the analysis section. Salary, project management, and overhead are internalized into the corresponding categories.

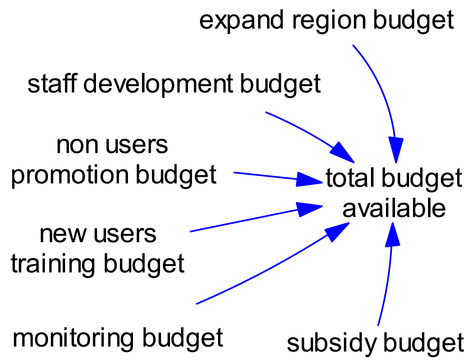


Figure 3 – Budget allocation sub-model

<u>Sub-model #2: Household segments by usage status (Figure 4)</u>

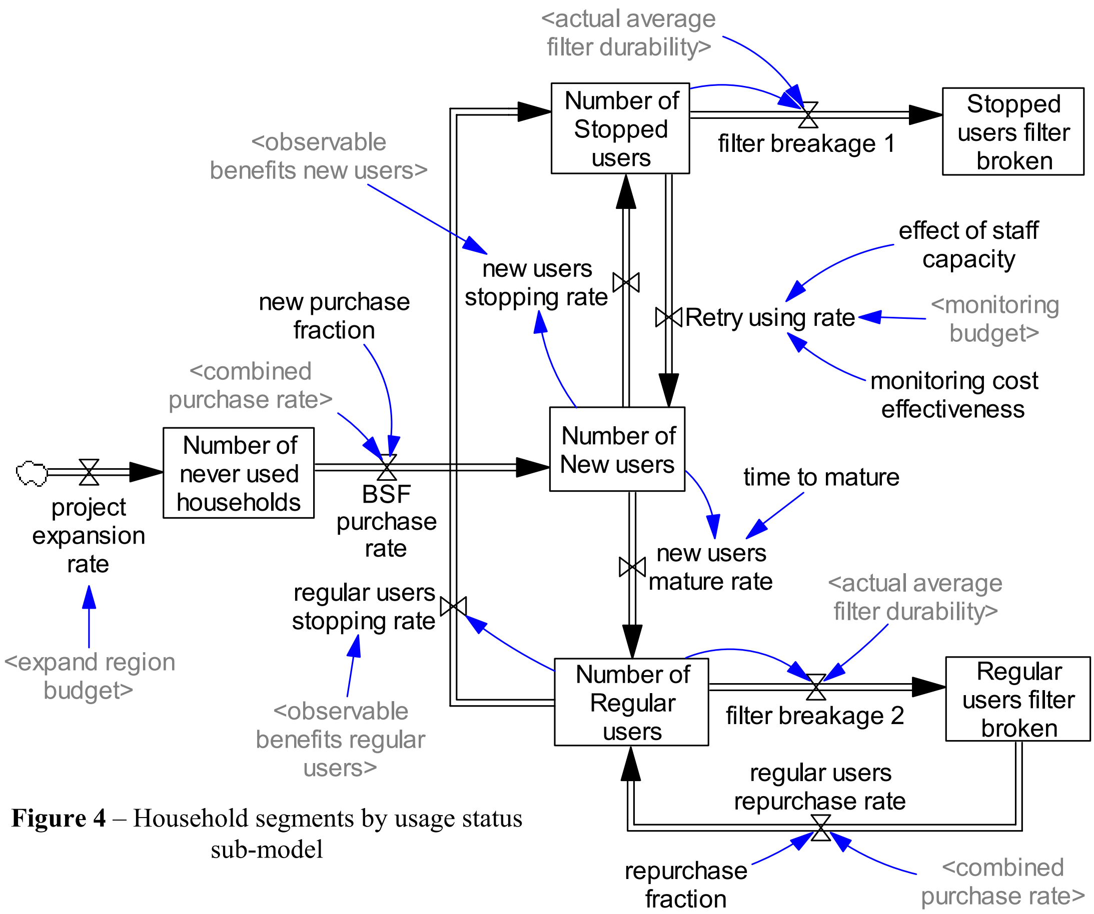


Figure 4 – Household segments by usage status sub-model

Starting from the left side, BSF can be made available to more areas if an expansion budget is available. Households have access to BSF only if the BSF program reaches their local areas. The newly added households are initially contained in the *Never used population* stock. Through promotion activities, these households will learn about the BSF. If they are interested and if they can afford, then they will purchase, and become *New Users*. *New Users* receive training on proper operation and maintenance of BSF. Depending on the observable benefits from the filters, new users will either discontinue due to dissatisfaction, or become *Regular Users*. This decision typically occurs within the first 3 months of usage. *Regular Users* will continue to use daily, until one of two things happen. First, regular users may stop because of minor technical problems that the users cannot solve, or better alternative technologies become available. Second, *Regular Users* may stop because the filter is broken and require a new replacement. If new BSF are available and affordable, the ex-regular users will repurchase. Monitoring and follow-up activities by field associates to revisit filter households can help to convince some of the *Stopped Users* to retry using again. If filters of *Stopped Users* become broken, or if they leave the heavy filter behind as they move to a new house, *Stopped Users* are unlikely to repurchase a new filter.

Sub-model #3: Supply Chain and Purchase Decision (Figure 5)

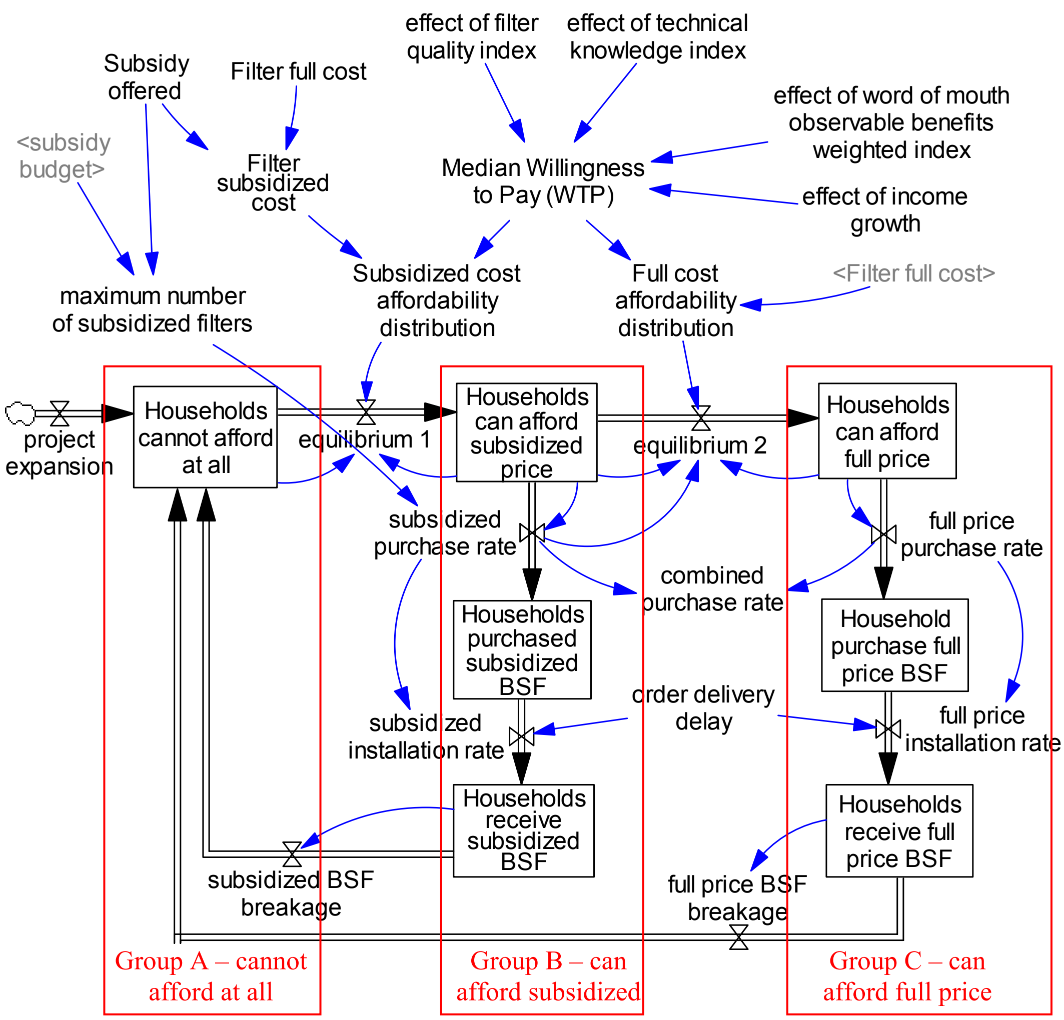
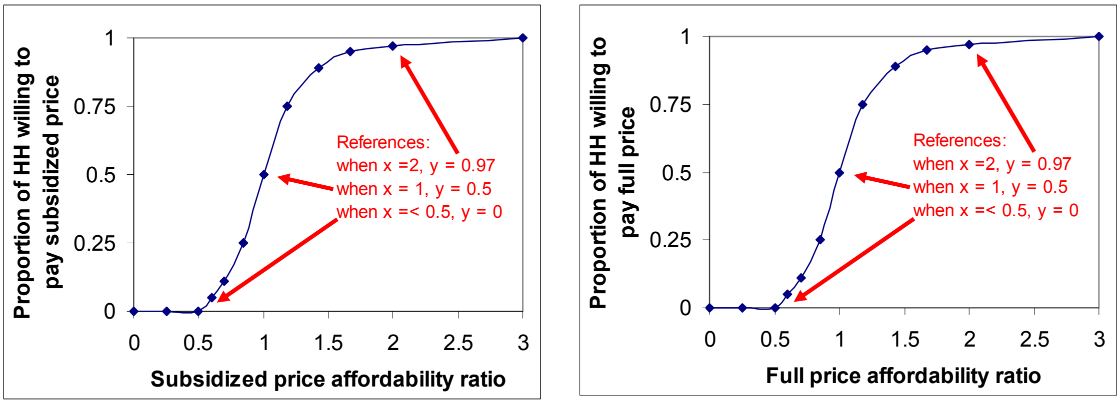


Figure 5 – Supply chain and purchase decision sub-model

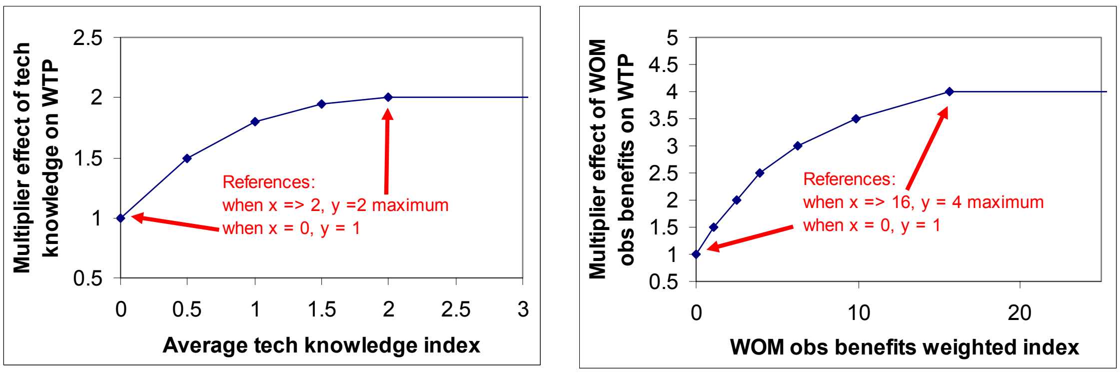
Income distribution and affordability distribution play a key role in determining households' adoption decision. All households under BSF program are divided into 3 groups. First group cannot afford even at the subsidized price. The second group can afford the subsidized price. This second group is further divided into 3 stocks – those who have not yet purchased, those who have placed an order, and those who have the filters installed. The last group can afford full price. This group is also divided into 3 stocks –not yet purchased, placed an order, and have installed filters.

The number of households in each of the 3 groups is calculated by first dividing the median WTP by the subsidized or full price to obtain an affordability ratio. This ratio is then compared to demand curves, as shown in Figures 6 and 7, to determine the proportion of households in each of the 3 groups. The demand curve is obtained from data analysis and stakeholders interviews. The equilibrium rate between the 3 groups is very fast to minimize memory effects and calculation errors.



Figures 6 & 7 – Demand curves relating income distribution to proportion can pay

The median WTP is defined as the price at which 50% of the entire population can afford. The median WTP is determined by the filter quality, households' technical knowledge, word-of-mouth (WOM) observable benefits strength, and income growth. Figures 8 and 9 show the effects of technical knowledge and word-of-mouth strength. WOM observable benefits has the greatest influence on WTP because in most rural village contexts, households' interest in an innovation is mildly dependent on their theoretical knowledge of the features of the technology, but highly dependent on favourable and immediate observable benefits, as well as from positive recommendations from neighbours and friends.



Figures 8 & 9 – Effects of technical knowledge and word of mouth strength on WTP

When subsidy is available, households from both group B and group C will try to purchase at the subsidized price. Purchase of subsidized filter will cease when there is no buyer, or the maximum number of subsidized filters is reached. In the latter case, group C households will pay the full price. The production capacity at DHAN is very large, and there is practically no limit as to the number of filters that can be produced.

Normally, there is a delay of 3 to 4 months between placing an order and installing filters, to take into account the time needed for demand list compilation, payment collection, filter production, filter transportation and installation. When filters are broken, the household is recycled back to the group A, B, C distribution immediately.

Sub-model #4: Technical Knowledge (Figure 10)

Technical knowledge refers to the households' conviction that water treatment and BSF are necessary, and the knowledge to operate and maintain BSF properly. In the model, one unit of technical knowledge is defined as the amount of awareness gain by a household from attending a ½ day workshop on HWTS and BSF, trained by staff with 1 year of direct experience in HWTS and BSF. This is the minimum level of technical knowledge needed to operate and maintain BSF properly, in order to realize the full benefits of BSF. Besides its relationship to BSF performance, when technical knowledge is high, households are willing to pay more for a BSF.

The technical knowledge of the 6 household usage segments (as in sub-model 2) is calculated independently. The basic structure for each segment is the same, but the parameter values are different. The part related to new users is shown in Figure 10. For non-users, technical knowledge can be gained through promotion and awareness generation activities. For new users, technical knowledge can be increased through new users training. For regular users and stopped users, technical knowledge can be increased through monitoring and follow-up activities. The actual amount of knowledge gained depends on the budget available, the cost effectiveness of that particular activity, and the staff capacity.

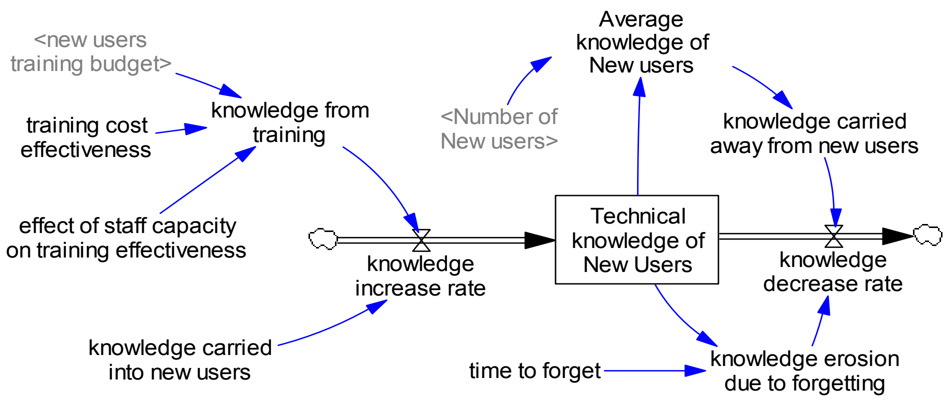


Figure 10 – New users technical knowledge sub-model

As households migrate from one segment to another (e.g. new users become regular users), they carry with them the average level of technical knowledge of the outgoing group, and add to the incoming group.

Knowledge can be lost due to forgetting. On average, non users lose their knowledge very quickly (in 6 months) because they have no filters at home. Regular users never lose their knowledge because they use the filter daily, and they are satisfied with the observable benefits of the filters. The *time to forget* for other groups is between 12 to 120 months.

Sub-model #5: Filter Durability (Figure 11)

Durability is defined as the average expected life of a filter, excluding breakage due to improper usage or excessive moving. The sand and gravel media in a BSF do not need replacement. The concrete box has an average life of about 30 years.

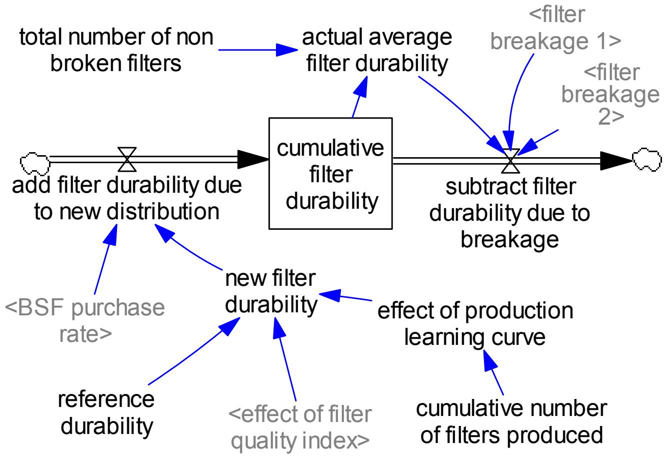


Figure 11 – Filter durability sub-model

New filter durability is equal to the reference durability modified by the effects of *production learning curve* and *filter input quality*. As the filter masons gain experience, filters quality and durability increases. Also, if high quality materials are used, and enhanced quality control and assurance mechanism are in place, the new filter durability will increase. Because durability is determined at "birth", the stock *cumulative filter durability* takes into consideration the different durability of all filter distributed.

Sub-model #6: Filter Inherent Perceived Benefits (Figure 12)

Perceived benefits are defined as favourable outcomes readily observed by filter users. The presence and the magnitude of these benefits is the primary factor contributing to user satisfaction, which in turns affects adoption decision. Examples of perceived benefits include water quality improvements (e.g. turbidity removal, improved taste), health benefits (e.g. less cold and cough), and social status (e.g. proud to be able to serve filtered water to guests).

Inherent is defined as the best achievable technical performance from an installed BSF. This is different from *observable*, which is what the filter users can actually experience and observed. *Observable* is often less than *inherent* because of improper operations can reduce the technologies performance.

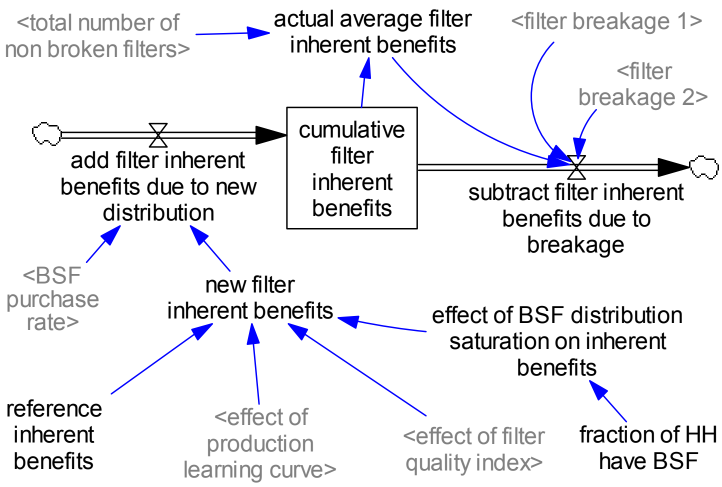


Figure 12 – Filter inherent perceived benefits sub-model

Therefore, *new filter inherent perceived benefits* is determined at “birth”. It is influenced by the *production learning curve*, *filter input quality*, and *BSF distribution saturation*. The effect of distribution saturation refers to the fact that filters installed at earlier adopters tend to have higher inherent perceived benefits compared to the filters installed at later adopters. It is because in any given region, there are variations between the households in terms of raw water quality, education, income, etc. Usually, households with the most favourable conditions or the greatest needs tend to obtain filters earlier. Filters installed at later adopters may be in households where the conditions are less favourable for BSF. Also, there are added social status and prestige associated with early adoption. The effect of saturation can be reduced by expanding the BSF program region to reach additional households.

Sub-model #7: Observable Perceived Benefits (Figure 13)

As with technical knowledge, the observable perceived benefits of the 6 household usage segments (as in sub-model 2) is calculated independently. The basic structure for each segment is the same, but the parameter values are different. The part related to new users is shown in Figure 13. As discussed earlier, adequate knowledge is needed to properly understand the operation and maintenance procedure, such that the users can derive the maximum benefits.

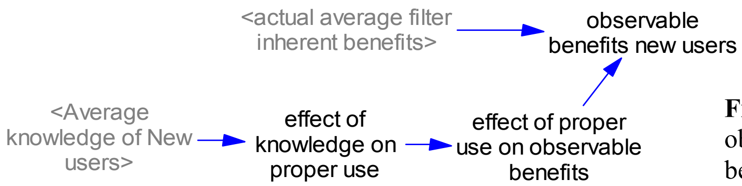


Figure 13 – New users observable perceived benefit sub-model

Observable perceived benefits have two important impacts on the over BSF dissemination process. First, if observable perceived benefits are high, then both new users and regular users are less likely to stop usage. Second, high observable perceived benefits help to stimulate and strengthen word-of-mouth effects, which lead to increased reputation of and interest in BSF among non-users.

Sub-model #8: Word-Of-Mouth Strength (Figure 14)

Word of mouth (WOM) refers what the neighbours and friends say about a technology. The experiences from adopters, either positive or negative, can significantly influence non-adopters’ adoption decision.

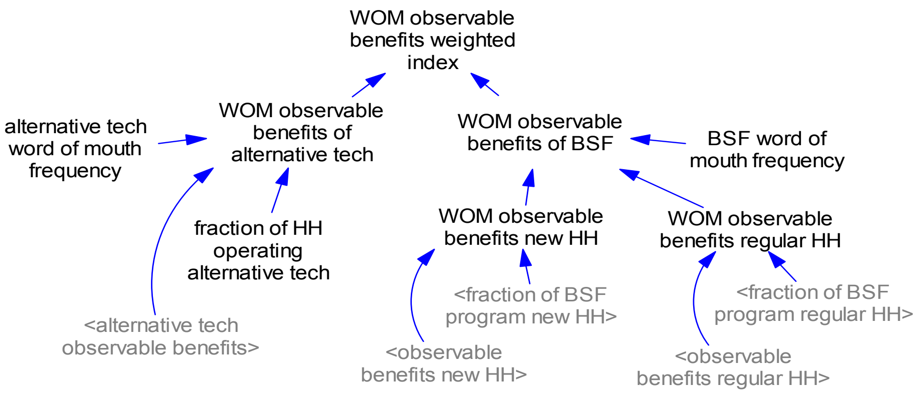


Figure 14 – Word of mouth strength sub-model

The strength of word of mouth is dependent on 3 factors. First factor is the actual observable perceived benefits of a technology. The higher the observable benefits, the more enthusiastic and convincing will the adopters' recommendation be. The second factor is the fraction of households who are actually using the filter. Households that do not have operational filters, or have stopped usage, have an overall neutral impact on word of mouth. Finally, the frequency of contact between adopters and non-adopters determines how frequency the non-adopters hear the experience from adopters. These three factors combine into the WOM *observable benefits of BSF*. The same can be calculated for the leading alternative technology. The ratio between the WOM observable benefits of the BSF vs. alternative technologies gives the *WOM observable benefits weighted index*. The higher the index, the more BSF is perceived to be positively recommended.

Sub-model #9: Staff Experience (Figure 15)

The experience and capacity of staff can significantly affect the effectiveness and efficiency of BSF program activities. Since inception, the BSF program is coordinated by a professional staff at the DHAN central office. The field level activities are mostly carried out by local field associates. Except for one full time BSF-dedicated field associate, all other staff involved generally spends 10% of their time on the BSF program, with the remaining 90% of their time on other non-BSF related projects.

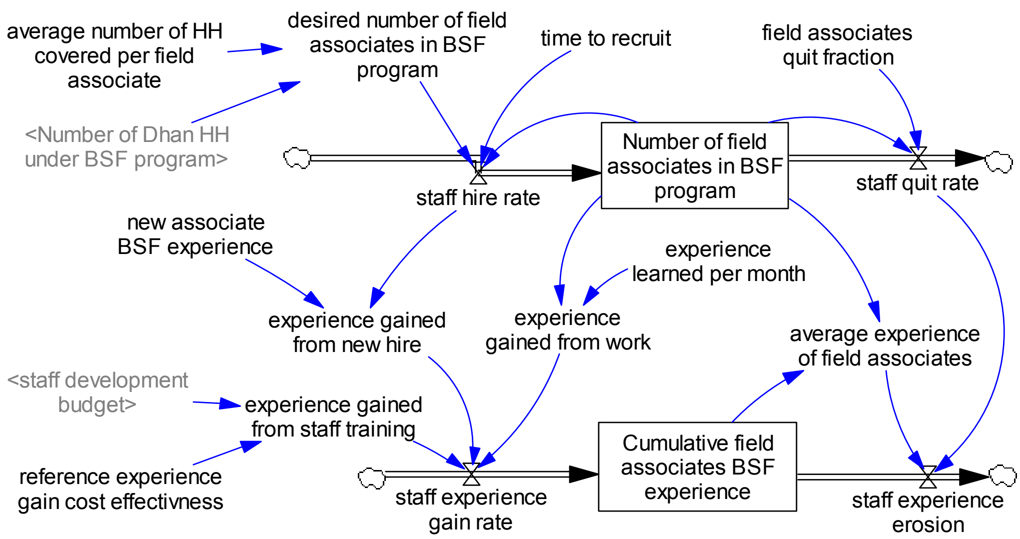


Figure 15 – Staff experience sub-model

As the BSF project expands, field associates are recruited to manage the new areas. Because BSF is a relatively new innovation, new associates generally have no prior experience. Experience can be gained from staff training activities, as well as from work. Only 0.1 month's worth of experience is gained per field associate per month because they only spend 10% of their time on BSF activities. DHAN places high emphasis to select field associates who are originally from the local program area. As such, field associates usually stay with DHAN for an average 4 years (quite high). When a staff quit, a new staff will be hired. However, experience will be lost. The average experience of field associates affects monitoring effectiveness and technical knowledge generation effectiveness in the model.

MODEL CALIBRATION

Historical project accounting information was analyzed and categorized into 6 budget items as in the model. Figure 16 shows the budget input into the model.

The first BSF project was funded by the Canadian High Commission, and lasted from month 0 to 22. In the initially months, the main activities were to establish a BSF production centre in Madurai, to select suitable villages for demonstration, to coordinate with the field associates, to train the field associates and filter construction crew on water, health, and BSF. In the middle phase of the project, focus was shifted to promotion and demand collection, as well as filters production and installation. Filter production and distribution continues to ramp up towards the last few months of the project, but new users training and monitoring gained prominence. Region expansion, staff development, and non-users promotion were very low at the end of the project.

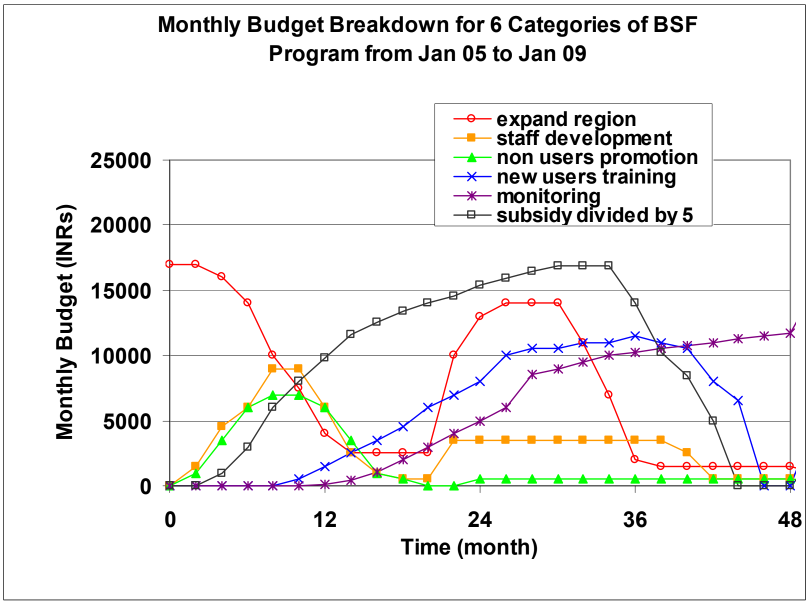


Figure 16 – Historical budget input to the model. Note: Because the subsidy budget is significantly higher than the other budget items, the graph shows the subsidy budget divided by 5, such that the relative trends for each budget item can easily be compared.

Immediately after the completion of this project, multiple new projects were initiated, starting with a large Novib/Oxfam tsunami project from month 22. In the first few months, considerable efforts were spent to expand the BSF program, so that the new filters would be introduced in new areas. District offices were contacted, and their local field associates were trained. Filter production and installation activities continued to increase, peaking at around month 30 to 36 (i.e. July to Dec 07). New users training and follow-up monitoring increased along with filter distribution. There were only little non-users promotion activities, because there were already many households who have heard about the BSF previously, and were willing to pay subsidized price.

After month 36, the majority of the project funds had been spent. Most budget categories experienced significant reduction. Monitoring was an exception, as this was funded by DHAN's own internal budget.

Figure 17 shows the model's prediction on the number of BSF produced and installed. The very good match between the model's predication and actual data, indicated by the high correlation coefficient values of 0.957 and 0.924, suggests that the model is calibrated appropriately.

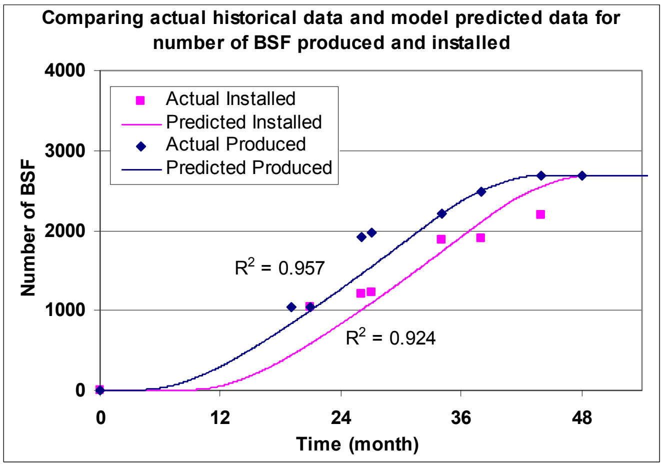


Figure 17 – Calibration of model against number of BSF produced and installed

PRELIMINARY ANALYSIS

The model was tested under 6 different future scenarios, and the model outputs are discussed below.

<u>Simulation run #1: No funding</u>

This scenario assumes that there is no new funding (internal and external) to support any further BSF activities from month 54 (July 09) onwards. All activities terminate. Figure 18 shows the model output on filter number and usage.

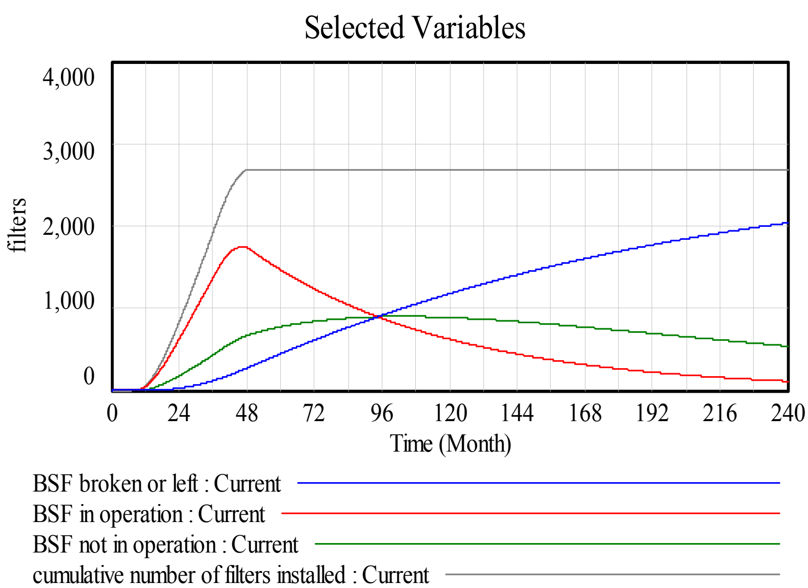


Figure 18 – Model output for simulation run #1: No Funding

The cumulative number of filters installed remains flat at 2690. No filter is distributed after month 48 because subsidy is unavailable and none of the households are willing to pay full price. The number of filters in operation (e.g. regular users) peaks at 1800 (out of 2690 filters) at month 48, and then drops to about 100 by month 240. This drop is because of two reasons. First, the filters of regular users are broken over time, but the regular users are unable to obtain new filters because no subsidy is available, and they are not willing to pay full price. Second, some regular users have stopped using, but there is no monitoring mechanism to bring these stopped users back to usage.

The main conclusion from this simulation run is that DHAN must find additional funds to support its BSF program, or else the whole program is predicted to fail eventually. When no new filters are distributed, and no monitoring mechanisms to bring stopped users back to usage, the number of regular users will ultimately decrease.

Simulation run #2: Minimal funding

This scenario assumes that there is no external support, and DHAN will only fund monitoring activities using internal resources from month 54 (July 09) onwards. The monitoring budget will increase from the month 48 (January 09) level to keep up with inflation only. Figure 19 shows the model output on filter number and usage.

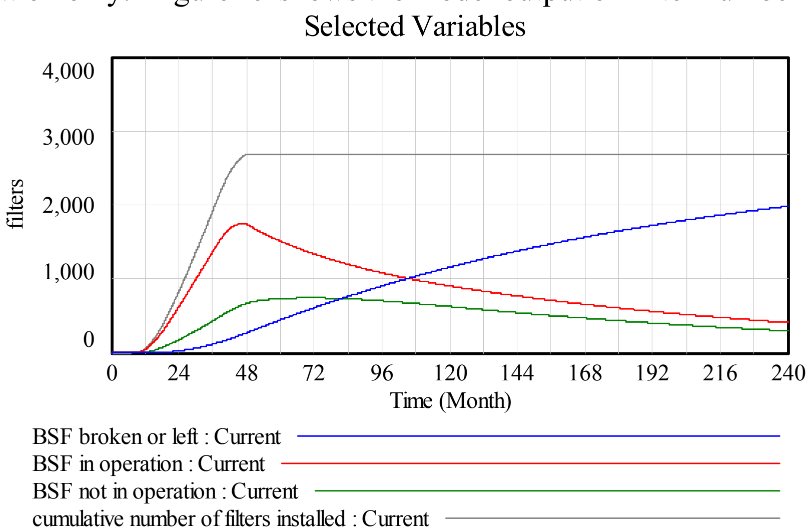


Figure 19 – Model output for simulation run #2: Minimal funding

Similar to simulation run #1, the cumulative number of filters ever installed remains flat at 2690, because subsidy is unavailable, and no household is willing to pay full price. However, the number of filters in operation (e.g. regular users) shows some improvements. From its peak at 1800 (out of 2690 filters) at month 48, it drops at a slower pace to arrive at about 500 by month 240. It is because monitoring substantially increased the technical knowledge of the regular users such that they can operate the filters correctly, and can obtain significantly higher level of observable perceived benefits. This results in higher satisfaction and lower stopping rate. Also, monitoring activities convinced certain stopped users to retry using.

Nevertheless, the overall results are still unsatisfactory. Monitoring can only slow down the drop in usage, but cannot reverse the trend to increase usage.

Simulation run #3: Steady funding, same budget allocation

This scenario assumes that total budget of 50,000 INRs/month + inflation will be supported from DHAN and donors, starting from month 54 (July 09) onwards. The budget is allocated at the same ratio as in the average of the past projects (i.e. expand region = 11%, staff development = 4.4%, non-users promotion = 2.4%, new users training = 7.6%, monitoring = 7.8%, and subsidy = 66.8%). Subsidy offered per filter decreases over time such that the subsidized price equals to the median willingness to pay (i.e. always 50% can afford). Figure 20 shows the model output on filter number and usage.

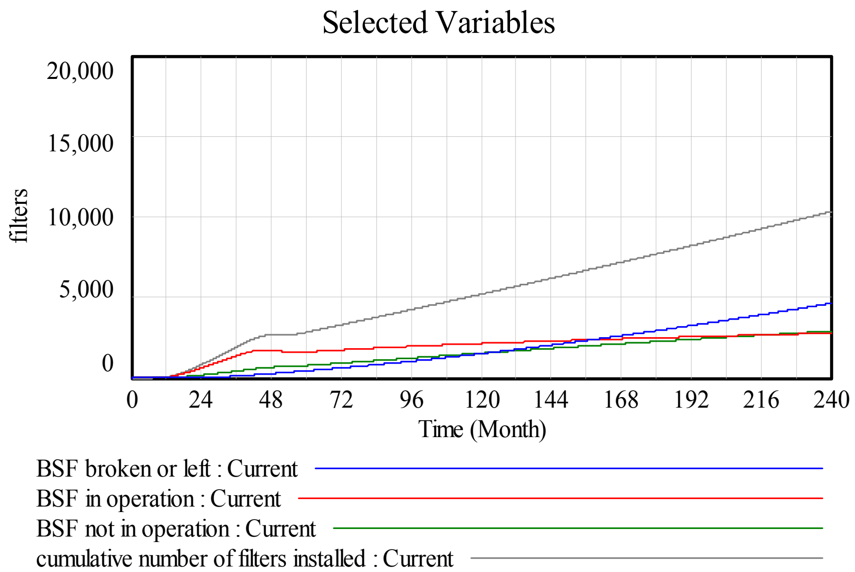


Figure 20 – Model output for simulation run #3: Steady funding at same budget allocation

In this scenario, the total number of filters ever distributed increases to over 10,000 due to the availability of subsidy. However, the number of filters in operation is disappointingly low, at around 2500 at month 240.

A closer investigation revealed that the median willingness to pay (WTP) increases so slowly that nobody is willing to pay full cost yet. WTP is mainly influenced by Word of Mouth, which actually drops significantly after month 48. There are two explanations for the drop in WOM. First, as the project expands quickly, filters are spread across many places. As such, a critical mass of adopters is never reached. Second, the new users training and monitoring budgets are flat (after accounting for inflation) but the number of filters continues to increase, new users and monitoring budgets are thus spread among too many households, and the quality of these activities suffers as a result. Households are inadequately trained on proper operation and maintenance. This leads in low observable benefits, and contributes to low WOM.

The key conclusion from this simulation run is that expanding too quickly, but without adequate funding support to accompany that growth, can stretch resources too thin. Stretched resources can inhibit healthy growth, as shown by the relatively flat level of filters in operation from month 48 to 240. The next simulation run will evaluate the outcome of a no-growth strategy.

Simulation run #4: Steady funding, no expansion, more monitoring

This scenario assumes a total budget of 50,000 INRs/month + inflation from month 54 (July 09) onwards. The project area does not expand. Monitoring and new users training are enhanced to consolidate efforts to the existing areas (i.e. expand region = 0%, staff development = 5%, non-users promotion = 0%, new users training = 10%, monitoring = 20%, and subsidy = 65%). Subsidy offered per filter decreases over time such that the subsidized price equals to the median willingness to pay. Figure 21 shows the model output on filter number and usage.

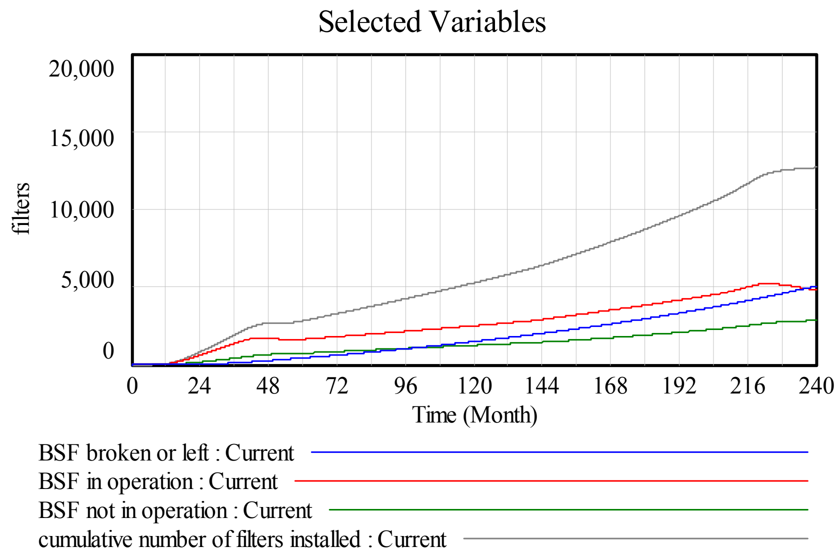


Figure 21 – Model output for simulation run #4: Steady funding but no expansion

Although this simulation and the simulation 3 have the same budget, there are two remarkable outcome differences. First, in this simulation, the total number of filters ever distributed is increased by about 2,500 to almost 13,000. It is because the willingness to pay increases more rapidly than in the previous simulation. This results in lower subsidy required per filter, so that the total subsidy budget can be shared among 2,500 more households. The second major difference is that the number of regular users increases to about 5,000, compared to only 2,500 in the previous simulation. The training and monitoring focus of this simulation generates higher level of technical knowledge among the regular users. As discussed earlier, high technical knowledge leads to proper use, high observable benefits, and low stopping rate.

Why does willingness to pay increases so rapidly in this simulation? The main reason is that the WOM steadily increases in this run. By concentrating the filter distribution to a small region, critical mass of adoptions appears to have been reached. In fact, starting in months 132, some households start to pay full price. The purchase was so intense that by month 216, half of the total households in the project area have obtained BSF. Because the subsidized price is set to equal to the median WTP, so only half of the total households can afford the subsidized price filters. The remaining half cannot. This means that all those who can afford the subsidized price have already purchased. There is nobody else left to purchase filters, unless the subsidized price is lower to attract the lower income groups. This situation explains the slight dip in filter distribution after month 216.

Simulation run #5: Growth funding, same budget allocation

This scenario assumes a total budget of 50,000 INRs/month + inflation, plus an additional annual increase of 15%, starting from month 54 (July 09) onwards. The budget is allocated at the same ratio as in the average of the past projects. Subsidy decreases over time such that the subsidized price equals to the median willingness to pay. Figure 22 shows the model output on filter number and usage.

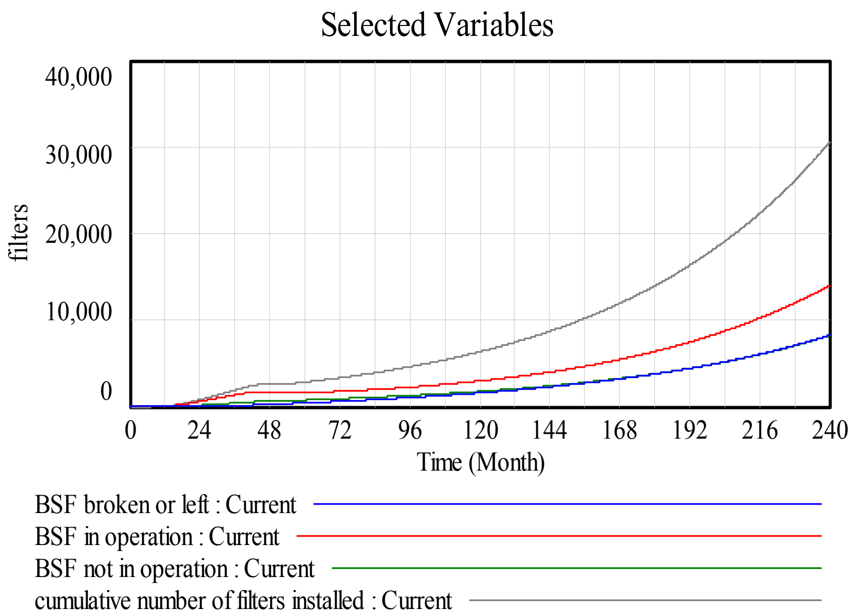


Figure 22 – Model output for simulation run #5: Growth funding at same budget allocation

In this scenario, the cumulative number of filters installed grows to just over 30,000 by month 240. The number of filters in operation grows to 14,000. Based on these results alone, this appears to be a successful outcome. However, the numbers behind this graph paint a different picture. This is a case of massive "dumping" of subsidized filters without adequate post distribution support.

First, the technical knowledge among households drops rather quickly since month 48. New users training and monitoring budgets, although increasing, appear unable to keep up with the surge in the number of filters distributed. Second, the rapid expansion to new regions results in very low concentration of filters per village. The BSF program coverage increased by about 85 times, from 15,000 households in month 48 to over 1.3 million households in month 240, but the total number of filters distributed increased by merely 11 times, from 2690 filters in month 48, to 31,000 filters in month 240. Critical mass of adopters appears never been reached.

As a result, the willingness to pay is very low. Actually, WTP in this scenario is almost the same as in simulation run #1. No households are willing to pay full price. If funding slows down or terminates beyond month 240, the apparent "success" of this scenario will quickly unravel, and will most likely follow the projections predicted by simulation runs #1 and #2.

Simulation run #6: Growth funding, slower expansion, more monitoring

This scenario assumes a total budget of 50,000 INRs/month + inflation, plus an additional annual increase of 15%, starting month 54 (July 09) onwards. The budget favours a slower expansion and more monitoring to consolidate efforts in existing areas (i.e. expand region = 1%, staff development = 5%, non-users promotion = 0%, new users training = 10%, monitoring = 20%, and subsidy = 64%). Subsidy decreases over time like previously. Figure 23 shows the model output.

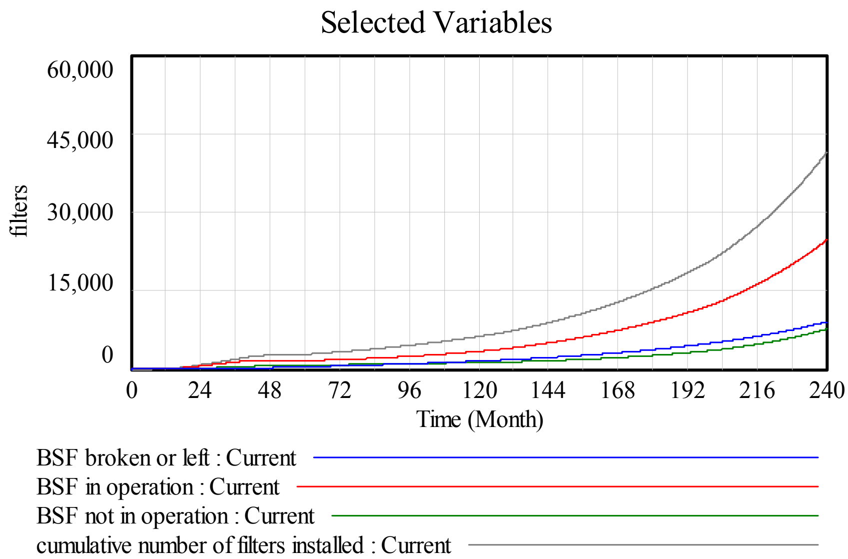


Figure 23 – Model output for simulation run #6: Growth funding, slow expansion

Compares to simulation #5 that has the same budget input, this simulation provides a better outcome. The total number of filters ever distributed is about 41,000 (10,000 more), and the number of filters in operation is about 24,000 (10,000 more). The main reason for the difference is that in simulation #6, almost 10,000 BSF are purchased at full price. Also, the WTP is much higher in simulation #6, so that the amount of subsidy offered per filter is lower, which allows more subsidized filters to be sold.

The technical knowledge is not very high yet. Placing more emphasis on new users training and monitoring can increase observable benefits, leading to higher WOM and subsequently WTP. It is possible to further optimize the budget allocation and subsidy to reach the lower income group, raise the WOM and WTP so that the continuation of the BSF program in the existing area will become self-sustainable.

SUMMARY FINDINGS

The 6 different simulation runs provided insightful understanding of the dynamics of DHAN's BSF dissemination process. The model not only predicts the obvious and measurable outcomes, such as filter sales, but also explains the rationales contributing to these outcomes. This gives the analyst deeper understanding of the root causes of any undesirable behaviour, rather than to just treat the apparent undesirable symptoms.

The above model analysis raised a key issue on sustainability. In the initial stage of DHAN's BSF program, DHAN may be tempted to expand the project area quickly in order to seed awareness and interest in BSF in many areas. This "entry strategy" has its merits, as this is the only way to reach millions of people in India lacking access to safe drinking water. However, significant resources are required to support such an initiative, and financial sustainability is hard to reach. On the other hand, if the objective is to become financially sustainable, then the "exit strategy" should emphasize resources consolidation in existing regions. Only in this way, WOM can increase quickly enough such that the WTP can increase to reach the full cost of the filter. Therefore, the twin goals of simultaneously expanding quickly and achieving financial sustainability appear to be difficult under the current BSF dissemination process.

NEXT STEPS

Two main categories of analysis will be conducted in the next few months on this India model. First, the effect of emphasizing other budget items, such as staff development, will be explored. This can help investigate how to optimize the budget allocation and subsidy (or profit) policy to obtain the most sustainable outcome, at a given level of funding. Second, model structures may be added or subtracted to evaluate the possibility to achieve high growth and high financial sustainability simultaneously.

In addition, models from Ghana (ceramic filter) and Nepal (household chlorination) will be formulated and analyzed. Comparisons of the three different models and their respective policy implications may yield further insight into whether HWTS dissemination process is regionally specific, or can be generalized for worldwide application.

CONCLUSIONS

Currently, over a billion people in the world lack access to safe drinking water, and HWTS have huge potential to serve the poor in rural and isolated regions where the needs are the greatest. Literature review showed that the HWTS dissemination process is complex. Viewing from different perspectives and their associated assumptions, many critical factors have been identified, and many recommendations have been proposed. There seems to be a lack of a holistic and systematic approach to incorporate the views from various perspectives. This research attempts to use system dynamics modelling tool, a novel approach, to characterize and analyze how HWTS deployment can be expanded. It is hoped that this research will assist policy-makers, government officials, field practitioners, donors, and researchers to appreciate the bigger picture of HWTS dissemination, to analyze existing HWTS programs, and to identify high impact, leveraged policies to expand implementation in a sustainable fashion.

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