Defining Common Parameters of Evaluations for Water Filtration Technologies in India

by

Jacqueline Nicole Durazo

Submitted to the Department of Mechanical Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Engineering as Recommended by the Department of Mechanical Engineering at the MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2014

© Massachusetts Institute of Technology 2014. All rights reserved.

Signature redacted

Author ........................................

Department of Mechanical Engineering

May 6, 2014

Signature redacted

Certified by ..............................................................

Daniel Frey

Professor of Mechanical Engineering

Thesis Supervisor

Signature redacted

Accepted by ..............................................................

Annette Hosoi

Professor of Mechanical Engineering

Undergraduate Officer
Defining Common Parameters of Evaluations for Water Filtration Technologies in India

by

Jacqueline Nicole Durazo

Submitted to the Department of Mechanical Engineering
on May 6, 2014, in partial fulfillment of the requirements for the degree of Bachelor of Science in Engineering as Recommended by the Department of Mechanical Engineering

Abstract

Nearly 1 billion people in the world today do not have access to safe drinking water. With almost 3.5 million of those people dying each year, this is no longer an issue we can pretend is of little importance. Of the deaths that occur each year, 84% are those of children and 98% occur in developing countries. Many companies have created water filtration technologies targeted for the population most affected, that is, those living in developing nations. In order to inform the user as well as gather data, several groups have conducted various evaluations on these products. A problem with the current system is that there is no consistent evaluation procedure. With the lack of a standardized procedure, come results that are difficult for the user, and evaluation team, to compare due to the lack of common criteria. For example, to evaluate product A on criterion 1 and product B on criterion 2 makes it difficult to then compare the results.

This paper qualitatively assessed three studies that evaluated various water filtration products in India. In order to help parse the information, matrices were created for the business, product, and monitoring and evaluation parameters of the studies. Some studies had parameters in common like testing contaminants removed; others suggested new parameters to consider such as ease of maintenance of the product. Each chapter explains the merits and disadvantages in their choice of test parameters.

At the end there is a suggested method which hopefully future universities, laboratories, and groups conducting evaluations will consider following. It is made of parameters that the studies evaluated had in common as well as ones that were found to be useful though perhaps not common. In conforming to a standard evaluation procedure, hopefully the discussion between groups and products will be more useful thus leading to better user-compliance and an increase in safe water consumed around the world.

Thesis Supervisor: Daniel Frey
Title: Professor of Mechanical Engineering
Acknowledgments

I would like to acknowledge Professor Dan Frey, Susan Murcott, and Derek Brine for their tremendous help with this thesis. I asked much of your time and bothered you each with many email. Thank you for never getting annoyed of me! (Or at least, hiding it well.)

I would also like to thank the amazing graduate students, staff at the Writing Center, and my two "sisters," all of whom have helped me to succeed in creating this thesis. In particular I would like to thank Victor, Chris, Natasha, and Sean; you each are so kind and I thank you for taking the time you did out of your busy schedules to help me.

Lastly, I would like to thank my family, the Solimans, and Morenos. My submission of this thesis marks the end of my undergraduate journey here at MIT— a journey that has only been made possible because of the sacrifices of many. Your efforts have not gone unnoticed and I cannot thank you enough. Worthy of particular note are my mother and brother, both have continued to be a source of inspiration, encouragement, and friendship. While I wrote this thesis, it is you two who helped guide my hands.
Contents

1 Introduction .................................................. 11

2 Explanation of the matrices ........................................... 13

3 A Toolkit For Monitoring And Evaluating Household Water Treatment And Safe Storage Programmes [1] ................................. 17
   3.1 Business ......................................................... 17
   3.2 Product: Technical .............................................. 18
   3.3 Product: Usability ................................................ 19
   3.4 Monitoring and Evaluation ...................................... 20

4 Status of Household Water Treatment and Safe Storage in 45 Countries and a Case Study in Northern India [2] ........................................ 23
   4.1 Business ......................................................... 23
   4.2 Product: Technical .............................................. 24
   4.3 Product: Usability ................................................ 26
   4.4 Monitoring and Evaluation ...................................... 27

   5.1 Business ......................................................... 29
   5.2 Product: Technical .............................................. 31
   5.3 Product: Usability ................................................ 31
   5.4 Monitoring and Evaluation ...................................... 33
6 Suggested Evaluation

6.1 Business ................................................................. 35
6.2 Product: Technical & Usability ................................. 37
6.3 Monitoring and Evaluation ................................. 39
List of Figures

2-1 A visual representation of the parameters, grouped under the parent group business, compiled from the papers I reviewed.

2-2 Similar to the business matrix, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the technical parameters of product testing.

2-3 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the usability parameters of product testing.

2-4 Similar to the previous matrices, this is a visual representation of the parameters grouped under the parent group M&E, compiled from the papers I reviewed.

3-1 A visual representation of the parameters, grouped under the parent group business. This is for the WHO article.

3-2 Similar to the business matrix, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the technical parameters of product testing as noted by WHO.
3-3 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the *usability* parameters of product testing as noted by WHO. .......................... 19

3-4 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group *M&E*, compiled from the paper I reviewed by WHO. .......................... 20

4-1 A visual representation of the parameters, grouped under the parent group *business*. This is for the Mehul thesis. ....................... 24

4-2 Similar to the business matrix, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the *technical* parameters of product testing as noted by Mehul. .......................... 25

4-3 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the *usability* parameters of product testing as noted by Mehul. .......................... 26

4-4 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group *M&E*, compiled from the paper I reviewed by Mehul. .......................... 27

5-1 A visual representation of the parameters, grouped under the parent group *business*. This is for the TARA article. ....................... 30

5-2 Similar to the business matrix, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the *technical* parameters of product testing as noted by TARA. .......................... 31
5-3 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the usability parameters of product testing as noted by TARA.

5-4 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group M&E, compiled from the paper I reviewed by TARA.

6-1 A visual representation of the parameters, grouped under the parent group business, I recommend an evaluation incorporate into their system.

6-2 Similar to the business matrix, a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the technical parameters of product testing. I recommend an evaluation incorporate these parameters into their system.

6-3 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the usability parameters of product testing. I recommend an evaluation incorporate these parameters into their system.

6-4 Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group M&E, that I recommend an evaluation integrate into their system.
Chapter 1

Introduction

Lack of access to safe water affects nearly 1 billion people in the world today. Water related illnesses causes the death of approximately 3.5 million people, 84% of whom are children and 98% of the deaths occur in developing countries [3]. Much technology has been created, pushed, and released to various markets, however there often still remains a disconnect between product penetration and availability. That is to say, increasingly products are becoming available in their desired markets, but for a plethora of reasons, they often fail to be actually used by their target audience [3]. Many evaluations have been conducted to help analyze why this occurs.

This thesis aims to help understand what certain evaluations did successfully, what they have in common, and what, if mentioned, failed to work. This is not the first evaluation of water filtration technologies designed for India, many others have been conducted, but this is more than just an evaluation of a product. The hope is to consolidate what are common parameters of various evaluations in order to help establish a more uniform and consistent procedure for future evaluations to consider following in their own studies. This is because of the several evaluations read and analyzed in this thesis, there lacks a consistency between them which makes it difficult to compare the products they are evaluating. Some evaluate techniques, others evaluate certain families of products, while others still do something in between and suggest what ought to be done for a certain type of product. With the lack of a consistent point of reference, how then is one expected to know which product is
better or more suitable for their target user?

The goal of this paper is to therefore provide a qualitative assessment in order to hopefully standardize evaluations of water technologies. Small research groups and laboratories at universities may find this useful for conducting future evaluations pertaining to water filtration technologies in India. Though the evaluations in this thesis discuss specifically India, it may be that the findings can be applied more broadly to products for the developing world if one disregards the parameters of the matrix (discussed later) that obviously relate to water filtration technologies (e.g. contaminants removed) and instead focuses on the parent group to which they apply (e.g. technical).

To clarify some terminology, implementer is the person or group responsible for selling or giving the water filtration device to the user or target household. Separate from the implementer, there is an evaluator or the team responsible for evaluating. Evaluators observe the interaction between the user and the product, the user and the implementer, as well as the user, implementer, and product independently.

Chapter 1 will briefly describe the matrix produced that summarizes the three studies read. Chapters 2 through 4 will review the literature that comprises the matrix. Chapter 5 will suggest a technique for CITE, a lab at MIT which is about to embark on the evaluation of water filtration products in India. The suggested evaluation makes note of common and useful parameters found in this literature review as well as notes from consultations with Susan Murcott, a senior lecturer at MIT specializing in water and sanitation in developing countries.
Chapter 2

Explanation of the matrices

In an effort to compile the papers I read and make their information easier to understand, the matrices below were created. They serve as a means to parse the literature I reviewed visually. As the papers and theses were read, I made note of which parameters of the matrix were mentioned, that is, the column titles running across the top of each chart. Because the parameters can be grouped under common parent groups of product development, as suggested by a graduate student I consulted, Natasha Wright, I gathered the parameters into the parent groups: Business, Product, and Monitoring and Evaluation (M&E).

Initially I thought only reviewing literature that evaluated the technical aspects of water filtration technologies would suffice. However, upon starting my research I found that much more than simply evaluating the technical aspects must be considered when determining the effectiveness of a product. Assuming that the ultimate goal of a water filtration product is to increase the consumption of clean water among the population who previously didn't have access to it, the definition of what is an effective product changes from the laboratory definition. One might, if ignoring the field integration of the product, simply evaluate the effectiveness of a product by conducting experiments such as bacteria kill rate and safe storage. These experiments are easily quantifiable and laboratory-friendly. However, as many of these papers will suggest, much more than that must be considered when dealing with developing country markets in this case, specifically India. Things such as user knowledge of what
to do or trained implementers out in the field are less quantifiable, but equally worth noting.

In the following chapters, it will be explained which studies included which parameters of an evaluation and why they found it to be important to do so. Hopefully from this, a more general and consistent process for evaluating water filtration systems in India may be adopted. At the very least, future evaluations will know which parameters have been used by other groups and why.

<table>
<thead>
<tr>
<th>Business</th>
<th>Number of units distributed/distribution partners</th>
<th>Size of distribution partners</th>
<th>Information relayed to customer</th>
<th>Reach of distribution partners</th>
<th>Manufacturing/supply choke points</th>
<th>Responsive ness of suppliers to customers</th>
<th>Quantity/Quality of contact with implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Jain, M.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>TARA</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2-1: A visual representation of the parameters, grouped under the parent group *business*, compiled from the papers I reviewed.

<table>
<thead>
<tr>
<th>Product</th>
<th>Technical</th>
<th>Pathogen kill rate</th>
<th>Flow rate</th>
<th>Contaminants Removed</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jain, M.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TARA</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2-2: Similar to the business matrix, this is a visual representation of the parameters, grouped under the parent group *product*, compiled from the papers I reviewed. In particular, this highlights the *technical* parameters of product testing.
### Figure 2-3:

<table>
<thead>
<tr>
<th>Product Usability</th>
<th>Durability</th>
<th>Affordability</th>
<th>Discarding of product</th>
<th>Storage capacity</th>
<th>Ease of maintenance</th>
<th>Reliability/product life</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jain, M.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TARA</td>
<td>x x x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2-3: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the *usability* parameters of product testing.

### Figure 2-4:

<table>
<thead>
<tr>
<th>M&amp;E</th>
<th>Budget: staff, water quality testing, data analysis</th>
<th>Review documentation</th>
<th>Interviews with staff post implementation</th>
<th>Understand factors contributing to use</th>
<th>Post-implementation phase</th>
<th>Proper training for implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>x</td>
<td>x x x</td>
<td>x</td>
<td>x x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Jain, M.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TARA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Figure 2-4: Similar to the previous matrices, this is a visual representation of the parameters grouped under the parent group M&E, compiled from the papers I reviewed.
3.1 Business

The World Health Organization (WHO) paper first and foremost states that it may be misleading to report the effectiveness of a product or its implementation plan based on the sheer numbers of products distributed [1]. For instance, many external or not noted events such as natural disasters or poorly accessible areas due to closed roads would affect the numbers of products distributed. Instead, the paper suggests one evaluate the implementation plan based on other factors.

The size of the distribution partners is something of which they made particular
Figure 3-1: A visual representation of the parameters, grouped under the parent group *business*. This is for the WHO article.

Note. It is recommended that the group conducting an evaluation work with local universities, research institutions, and government ministries. In partnering with these groups, it is stated that the group conducting the evaluation could save on the costs of data collection, analysis, and reporting [1].

Lastly, it is stated that both the quantity and quality of contact between the users and the implementers can provide much insight into the success of the implementation of a product [1]. To measure the quantity is rather straightforward and can be monitored with things such as number of work logs and number of visits. However, the difficulty lies with measuring the quality of interaction, that is to say, the time spent on training materials, the ability for implementers to adapt their behavior to the situation, and the knowledge they retain at all times. This may require more elaborate methods such as observing the training of implementers, also suggested was the delivery of a short quiz to test the knowledge of the beneficiary. As stated in more detail in Chapter 3, it is extremely important to make sure that the implementers of whichever product the group is evaluating, are adequately trained.

### 3.2 Product: Technical

This study primarily focused on the M&E and Business aspects of an evaluation, however it did mention two components of the product that an evaluating group should research.

The first is contaminants removed which is the basic test to make sure that the product being distributed or sold actually is capable of reducing microbial contam-
The obvious conclusion to be made is that non-functioning or poor quality products will not be effective in the home [1]. There are several suggested tests to run such as: turbidity, residual chlorine levels, E. Coli and thermotolerant coliform bacteria, and arsenic and fluoride. These are considered the most common water testing considerations [1]. Of course, the tests to conduct would be determined by the water source and the product. Furthermore, it is recommended that Household Water Treatment and Safe Storage (HWTS) efforts follow WHO performance recommendations.

### 3.3 Product: Usability

The second product related parameter pertains more to user-integration: affordability. It makes sense that the product should be affordable by the families using it. Prior to choosing which products a group will endorse, some research should be
conducted to determine if the local selling price of the product of interest is actually affordable by those most in need of it. Another point to consider is whether or not it is sponsored by an NGO or similar group who will subsidize or completely donate said products to the target audience.

3.4 Monitoring and Evaluation

<table>
<thead>
<tr>
<th>M&amp;E</th>
<th>Budget: staff, water quality testing, data analysis</th>
<th>Review documentation</th>
<th>Interviews with staff post implementation</th>
<th>Understand factors contributing to use</th>
<th>Post-implementation phase</th>
<th>Proper training for implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 3-4: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group M&E, compiled from the paper I reviewed by WHO.

Sometimes overlooked or understated is the budget for conducting an evaluation. Not that money or the cost of performing an evaluation is forgotten, but what is being sacrificed to fund more fully other aspects of the evaluation is often overlooked. WHO recommends that a coordinator be chosen to be in charge of the monitoring and evaluation team. Furthermore, it is recommended that when starting to conduct an evaluation, the person in charge should be familiar with managing staff, setting budgets, and should be comfortable with the responsibility of implementing M&E activities and disseminating the information from the M&E program [1]. This study suggests that a proper evaluation should allocate sufficient funds for staffing, transportation, equipment, water quality testing, and data entry and analysis [1].

In addition to the coordinator, it is essential that all staff members keep clear records and document the whole process so that beneficiaries may more clearly be aware of what has been done and why. This will be helpful in the moment but also later when, as recommended by WHO, a post-implementation review of all documentation is conducted to better understand how the process was developed and
implemented. It is also recommended that in addition to reviewing the documentation, interviewing program staff should occur to make note of what did and did not go according to plan during the implementation process.

Another important aspect to incorporate into one's evaluation technique is the necessity to understand the factors that contributed to, or detracted from, proper use of the product. In some cases, inconsistent use or non-use could be the result of poor implementation. For example, use of the technology could conflict with spiritual or cultural beliefs, or consumers were not properly informed by the implementer on how to clean or maintain the device thus resulting in improper usage. All such instances should be documented.

Lastly, it is crucial that post-implementation monitoring occur. WHO says that this phase should primarily focus on the ongoing availability of user support, supply chains, and continued product use and education services. That is to say, an evaluation should make notice of what support and education programs are made available, and if the means by which they are made available are easily accessible for the target audience.
Chapter 4

Status of Household Water Treatment and Safe Storage in 45 Countries and a Case Study in Northern India [2]

In his masters thesis, Jain explored what was the current practice of water purification and observed how a local group suggested new products to their target audience. Specifically, PATH India in New Delhi suggested he partner with AED in Lucknow to conduct the field studies. He also worked with a partner NGO of AED, Pratinidhi.

4.1 Business

Jain did a great deal of background research into what type of water was being consumed before ever addressing which products were available in the area. There is a paramount importance placed on the analysis of the water source for each household. Of the survey he conducted, the first asked approximately six questions to determine the quality of the water source for the household. He then asked several more questions regarding treatment practices before finally addressing specific products.

Jain mentioned that PATH suggested he work with a local group to help gain
access to the local people. Contrasting his approach of gathering information before mentioning products, the company he is partnered with, Pratinidhi, went to a household with an already made 3-step market strategy plan. The outline of their plan was simple:

1. Test every 10th household for the presence/absence of hydrogen sulfide bacteria using an appropriate test.

2. Return to the household to show the results of the test and sell one of three pre-determined products: Pureit filters, SafeWat, and Aquatabs (the latter two are chlorine products)

3. Perform a follow-up visit approximately one week after Step 2.

The problem with this approach is that only three products are ever suggested as a possibility. Furthermore, limiting ones options to those three completely disregards the water source, which perhaps could be best treated via other means.

4.2 Product: Technical

In addition to the anthropological information he gathered, Jain conducted several technical tests to determine information about the water quality. Specifically he found that approximately 40% of households are exposed to high-risk levels of contaminated water, while 50% are exposed to low-risk levels of contamination [2]. It was also noted
that it is difficult to determine whether or not the contamination was due to point of use consumption or another cause.

To test the level of contamination in the water, Jain conducted two tests. One was an in-field test, an EC-Kit test, which gave results without laboratory assistance. The other was a Multiple Tube Fermentation laboratory test which required the water sample to be sent to IIT Delhi for analysis. The results showed that the EC-Kit test produced more signs of contamination than the laboratory test [2]. There was some ambiguity with the results, however, as there was an 18-hour time difference between the in-field EC and in-laboratory tests. This, along with possible transportation contamination, could explain a difference in results. It is suggested that EC and in-laboratory tests be run at the same time in order to clarify any discrepancies. That is to say, if possible, it is best to run the EC test in-field as well as in the where the other test is being conducted. This would eliminate uncertainty of contamination due to transportation, as well as any discrepancies due to time delay. For future testing and if only one can be chosen though, it may be worthwhile for groups to consider using the EC-Kit test for in-field, immediate analysis.

He made note that the three following reasons could all contribute to the consumption of unclean water:

1. Improper storage practices
2. Inadequate servicing and maintenance of the product
3. Using the product beyond its expiration date
In addition to the efficacy of the actual product being sold, Jain also recorded how many users were using the product beyond its expiration date, hence source three listed above of possible reasons for unclean water consumption.

Surprisingly the only paper that I have read to make note of this, Jain makes the obvious statement that some failure of the product can be largely due to the materials chosen. In this study, the product Jain evaluates fails due to a large physical gap that occurs over time in the product. This could be due to various reasons, most of which rely on material properties. He argues that much of this improper use could have been prevented had higher quality control testing been performed on the product before it went to market. Therefore, he also recommends that each product require more extensive quality control in the product development phase.

### 4.3 Product: Usability

<table>
<thead>
<tr>
<th>Product</th>
<th>Usability</th>
<th>Durability</th>
<th>Affordability</th>
<th>Discarding of product</th>
<th>Storage capacity</th>
<th>Ease of maintenance</th>
<th>Reliability/product life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jain, M.</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4-3: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the *usability* parameters of product testing as noted by Mehul.

In addition to product failure due to material properties, another cause could be due to lack of proper maintenance by the user. He made note that with adequate instruction, it would be easy enough for users to know what to do to properly maintain it. This of course, depends on adequately prepared implementers, which should be of paramount importance, as discussed in the next section. It would be worth noting under what circumstances the product has been tested so as to be found durable enough for the situation in which the user lives.

Lastly, he noted that storage capacity is important. As mentioned, it is often
the containers that people store their water in that contaminates the water. Be it containers that leave the water open to the environment or simply dirty containers, a device that can store the water it has cleaned is of more use than one that does not provide such an affordance.

4.4 Monitoring and Evaluation

<table>
<thead>
<tr>
<th>M&amp;E</th>
<th>Budget: staff, water quality testing, data analysis</th>
<th>Review documentation</th>
<th>Interviews with staff post implementation</th>
<th>Understand factors contributing to use</th>
<th>Post-implementation phase</th>
<th>Proper training for implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jain, M.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4-4: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group M&E, compiled from the paper I reviewed by Mehul.

Upon experiencing first hand interviewing various households with the local group of implementers from the NGO, Pratinidhi, he partnered with, Jain noted some very disturbing inadequacies of the staff members. First he noted that not only did the implementers not know of other products to discuss with the household members if the family asked about other options, but the implementers also didn’t know of any other products to suggest if the household desired a different product than one of the three the NGO offered. Furthermore, sometimes they were not even able to answer questions about the products they were selling. In a few cases, they even instructed the household incorrectly about general water sanitation habits. For example, some staff members told household members that boiling water was an inefficient way to treat drinking water [2].

As mentioned in the previous section, improper instruction leads ultimately to improper water treatment. Be it the lack of knowledge about how to maintain the product or the purchase of a product that is in fact not the best fit for the users needs, the users knowledge of what to do heavily relies on how the implementer has instructed them. It was noted that many users complained of a lack of responsiveness from the
supplier or local store from which they bought the product. If one experiences a lack in proper use, it may be worth interviewing the families to see whether or not the user has sought out help or guidance and whether or not they have been successful in attaining said assistance.
Chapter 5


This study served to educate its reader on the current practices of several specific products currently on the market for water filtration. While this study focuses on specific (nano) technologies for evaluation, it still comes to the same conclusion, as expressed in other chapters, that there is a disconnect between the user uptake and the availability of the product on the market. It is one matter to provide a technology that can purify water in the way needed, but it is a different obstacle to provide that technology in a manner that makes it accessible and desirable by the target consumer.

5.1 Business

This study makes particular note that the business providing the product ought to be sure to provide information on proper usage to its consumer. Previously mentioned, by Jain, it was stated that the implementer should be adequately trained. While this is true, this study also states that the supplier should be able to supply information
Figure 5-1: A visual representation of the parameters, grouped under the parent group *business*. This is for the TARA article.

about the pros and cons of their product. Furthermore, the supplier should note what are the benefits from making the switch for the user and losses associated with the current system. Currently however, it is unlikely to find such information about a product directly sold with the product, thus the consumer is left to make a rather blind and uninformed decision. Something to keep in mind when conducting an interview is how much background knowledge did the customer have when they first made the purchase. According to TARA, the disclosure levels of said information for the area of India they were in, and the country at large, were low.

Also stated in the study was that marketing is often underused in advertising and informing the user of the pros and cons of using the product. A preliminary survey conducted showed that most customers do not know anything about the technology they are buying, and even less the benefits and reasoning for doing so. Like previously mentioned in Chapter 3, TARA also mentioned that the responsiveness of the company to the consumer regarding customer dissatisfaction or inquiries should be quick and adequate to respond.

It is also stated that partnering with local NGOs and micro-finance institutions is a recommended way to ensure the evaluating teams reach. Specifically its recommended that the business model of producer-wholesaler-customer be followed to minimize overhead costs thus enabling the sale of technologies at the cheapest and most affordable prices to the consumer.
Figure 5-2: Similar to the business matrix, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the technical parameters of product testing as noted by TARA.

5.2 Product: Technical

In this, they made note to evaluate two specific technical aspects: flow rate and the ability of the product to remove the contaminants. The only information its chart specifies is what type of contaminant is removed, that is, bacterial, oil, sand, etc. Furthermore, there lacks a consistency in the detail and terminology used to define the row addressing the contaminants removed making it difficult to compare products in even the same study. For the flow rate it simply listed the liters per hour cleaned. Of the tests this study performs and records the results, nowhere does it make mention as to why it performs said tests. A problem with not specifying why the study performed the tests that they did is that future studies will not be able to reason whether or not said tests are necessary for their study.

5.3 Product: Usability

Figure 5-3: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the usability parameters of product testing as noted by TARA.
It is stated that finding the right balance in the supply stage between the costs and the customer demand and satisfaction, is critical. This study states that the two things that influence customer decision are the brand name and the cost of the product. Marketing is said to play a crucial role in establishing a value for the product as well as creating a brand name.

TARA found it necessary to make note of which products also store the water they filter. Again, they do not specify as to why they performed this evaluation parameter. However, in addition to generating clean water, a good selling point is the safe storage of the cleaned water, as it is known that often it is the storage of water that leads to contamination.

Once the right product has been selected, it is important that the users know how to properly maintain the product, as previously mentioned in other chapters. This study makes notes that most filters on the purification units need to be replaced at some point. Although the more advanced models have their companies replace the filters, the cheaper, less advanced, and therefore perhaps more likely to be products of interest for the target audience, have no such service. Rather, they often have an indicator light that once it goes off, they will have to either buy a new unit or replace the filter in their homes.

This is the only study I have reviewed that mentions the need to educate the consumer in proper disposal of the product. TARA even remarked that other studies and stakeholders often find this point in the products life cycle to not be of great importance, and stresses that that mentality must change. Given the hope is that more people will acquire more filtration technologies, then it makes sense that disposal, as these products become bought and used, needs to be addressed adequately so as to make sure that we are not preparing ourselves for another problem to be dealt with in the future. As such, TARA suggests that monitoring programs be made to ensure that along with proper use of the product, the users are also properly disposing of them in their designated spaces. The need for proper disposal is noted for environmental as well as biohazard reasons, as elaborated on in Chapter 5.
5.4 Monitoring and Evaluation

<table>
<thead>
<tr>
<th>M&amp;E</th>
<th>Budget: staff, water quality testing, data analysis</th>
<th>Review documentation</th>
<th>Interviews with staff post implementation</th>
<th>Understand factors contributing to use</th>
<th>Post-implementation phase</th>
<th>Proper training for implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARA</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 5-4: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group M&E, compiled from the paper I reviewed by TARA.

The study states that risk management should be a high priority of any evaluation team given the potential hazards that may arise during the life cycle, from point of purchase to proper disposal. Therefore, risk management should be a critical component of the process to bring a product to market. This study further elaborates and says that the key failures of many studies is the lack of emphasis placed on risk management and poor information disclosure to the consumers. A key solution to risk management is to properly train implementers to thus make sure that accurate information is being relayed to the customer.

Because it is likely that there will be many stakeholders involved, it is strongly suggested that a clear and organized flow of information occur between all groups. A review of all documentation may also be found useful for the parties involved in the evaluation.
Chapter 6

Suggested Evaluation

After reading and reviewing the papers mentioned above, I met with several faculty members at MIT to discuss product testing, monitoring, and evaluating. From the reading and those conversations, a suggested evaluation can be found in the matrices below. The following sections explain, in similar fashion to the previous chapters, each parent group (Business, Product, and M&E) of parameters and why I recommend future studies integrate said parameters into their work.

6.1 Business

<table>
<thead>
<tr>
<th>Business</th>
<th>Number of units distributed/distribution partners</th>
<th>Size of distribution partners</th>
<th>Information relayed to customer</th>
<th>Reach of distribution partners</th>
<th>Manufacturing/supply choke points</th>
<th>Responsive ness of suppliers to customers</th>
<th>Quantity/Quality of contact with implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUGGESTED</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 6-1: A visual representation of the parameters, grouped under the parent group *business*, I recommend an evaluation incorporate into their system.

While there are many parameters a study could consider, I would recommend that an evaluation focus its efforts on analyzing: size of distribution partners, information relayed to the customer, reach of distribution partners (closely tied with the size),
responsiveness of supplies to customers, and quantity/quality of contact with the beneficiaries.

As mentioned in the previous chapters, the success of a product depends on many parameters; chief among them is user-knowledge and support. The more contact with the supplier or group who gave or sold the product to the user, the more likely the user is to know who to ask for help. A remote and small distribution group is less likely to be easily accessible to their user than a group who frequents the town and is a trusted local group with knowledge of the local culture. Essentially, a balance between social and financial capital must be met for the implementers to be optimally effective.

The information relayed to customer generally means the information relayed to customer at time of purchase, which is something that should be improved so that the customer has a better ability to make a wise purchase. Equally important however is the support for the users while they own the product. Should something go wrong or need to be replaced, the responsiveness of the supplier of the product will greatly determine whether or not the product is being used correctly and therefore whether or not the family is consuming safe water for drinking.

Lastly, the quality and quantity of the contact with the beneficiaries should be observed. If the distribution group is often available as documented via paper work and logged visits, but is not actually useful or knowledgeable, nothing is gained. As such, the quality, perhaps via short quizzes to test on-the-spot knowledge or perhaps direct household feedback would be a good means to measure that knowledge. Based on conversations with Susan Murcott and others, the risk with directly questioning the user, is that often the consumer will be shy and hesitant to complain. Put in colloquial terms, people are unlikely to bite the hand that feeds them. Because of this, I recommend that a direct method testing the implementer knowledge and interviewing them with how the observe and interact with their users will provide more accurate information.
6.2 Product: Technical & Usability

<table>
<thead>
<tr>
<th>Product</th>
<th>Technical</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flow rate</td>
<td>Contaminants Removed</td>
<td>Material</td>
<td></td>
</tr>
<tr>
<td>SUGGESTED</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6-2: Similar to the business matrix, a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the technical parameters of product testing. I recommend an evaluation incorporate these parameters into their system.

<table>
<thead>
<tr>
<th>Product</th>
<th>Usability</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Durability</td>
<td>Affordability</td>
<td>Discarding of product</td>
<td>Storage capacity</td>
<td>Ease of maintenance</td>
</tr>
<tr>
<td>SUGGESTED</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 6-3: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group product, compiled from the papers I reviewed. In particular, this highlights the usability parameters of product testing. I recommend an evaluation incorporate these parameters into their system.

To my surprise I found that when evaluating a water filtration technology, a large amount of the evaluation will be on aspects other than strict functionality of the product. In starting this thesis I assumed that the best method would be to evaluate what I call hard laboratory tests to determine things like flow rate, effectiveness at removing contaminants, etc. While these are certainly important tests, a useful evaluation is comprised of more than solely laboratory tests. The company that has produced the product should have gone through similar quality control tests when designing the product before launching it to market.

Instead of performing such laboratory tests, I recommend that one perform a crucial laboratory test to check that the product is indeed removing contaminants and then focus its efforts on other aspects of product evaluation. A promising test to
perform, though may require more testing to verify its accuracy, is the EC-Kit test. Mehul Jain, and masters student for Susan Murcott, used this test in his thesis. It proved to be more sensitive and able to identify more pathogens than the laboratory test. In-home testing, which can provide immediate results and be easily understood by the household, is a great way to show the users the need for clean water, according to Murcott.

In terms of more user-centric design, affordability should be researched. It makes sense that this would be a parameter evaluated, but not all evaluations mentioned this. While a company may go through great lengths to make their product costs 2USD, a seemingly low price for example, if the product breaks within a month then the cost of replacing that product also needs to be considered. From considering the cost associated with a product, one can see the importance of the parameter to consider reliability/product life. To either repair or replace the product, this also requires the users to potentially interact with the supplier. If the customer cannot easily access the supplier, then the inconvenience of needing to replace or fix the product increases greatly. With that, the probability that the user will start consuming unsafe drinking water also increases, simply because of the trouble associated with product.

Another closely related parameter is the ease of maintenance of the product for the user. It should be noted how easy the users find the product to maintain properly. As mentioned in other papers, maintenance is paramount in the delivery of safe water to the household. Furthermore, it makes sense that while the quality control in a laboratory may be easy, it may not be easy for the actual user in field. A simple test of watching to see if the user properly knows how to maintain the product and when they need to fix or replace it should suffice in testing this parameter.

Safe storage of cleaned water is equally important as it has been well documented that the source of contamination can often be the vessel in which the water is stored after the sanitizing process. For this reason, I recommend that the devices ability to store the water it cleaned be assessed. A product that ensures no post-cleaning contamination of the water would be of greater use than one that does not.

Lastly, proper disposal of the device did not seem like a parameter worth noting
but upon reading and thinking about it, I believe that this could present a very challenging problem in the future if not considered now. The population we seek to address is approximately one billion people. It makes sense then that as the sales of these technologies increases and they get used and then replaced, that they will make an ever-growing contribution to waste. As such, a device that either minimizes waste or has a recycle/sell back program better prevents this issue from being a problem in the future than one who simply does not consider this aspect of the products life. Noting what are the current practices for discarding the device could also help understand a source of water contamination. Once finished, the device could potentially pose a health threat and contaminate the water near it if simply buried or disposed of near a body of water from which people drink. Needless to say, this parameter of the products life cannot be ignored and should be recorded in ones evaluation.

6.3 Monitoring and Evaluation

<table>
<thead>
<tr>
<th>M&amp;E</th>
<th>Budget: staff, water quality testing, data analysis</th>
<th>Review documentation</th>
<th>Interviews with staff post implementation</th>
<th>Understand factors contributing to use</th>
<th>Post-implementation phase</th>
<th>Proper training for implementers</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUGGESTED</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 6-4: Similar to the previous matrices, this is a visual representation of the parameters, grouped under the parent group M&E, that I recommend an evaluation integrate into their system.

If the ultimate goal of an evaluation is to provide knowledge that should help with the increase in consumption of safe drinking water, then the parameters that fall under monitoring and evaluation cannot be overlooked. Prior to doing research I knew that to some extent user-centric design was needed, but thought that primarily meant to keep in mind the user when designing the product prior to launching it in the market. While that is true, for the purposes of evaluating already existing products,
one should incorporate a similar mindset in designing the evaluation as opposed to the product alone. Questions like, what are the goals of an evaluation? How might those be described in terms that matter to the user? And how does a group measure that? All of these considerations help focus on the user while creating the evaluation.

First, a proper budget should be established and point person to manage that should be chosen. As the project goes on, it is extremely important that a systems integrator be established to keep track of the budget and also who is doing what. While proper distribution of the workload is important, it is equally important to ensure that someone be the person that any staff member can come to with a question and receive either an answer or be directed to the right person.

Once the lead person has been determined, we now must address actually performing the evaluation. We established that ultimately we want the user to consume safe water. With that goal, there are several contributing factors; beginning with the user must be informed of what is the problem in the first place. This is where a properly trained implementer is crucial. As implementers are often the first person to inform the household of the problems associated with drinking contaminated water, it is essential that the implementer be well versed in the matter. Specifically, the implementer should be able to address three main issues:

1. What is the current water source?

2. Answer any questions about suggested products to use.

3. Answer questions, or know who to refer the user to, regarding questions about other options and products.

First it is of paramount importance to identify the water source. From that, one can determine appropriate types of water filtration systems. Unlike the NGO in the study from Chapter 3, the implementers should not go to the household assuming that a predetermined set of products would work. Microbial as opposed to chemical and other types of contamination would require different products for proper treatment. It makes sense that the water source should be inspected first, but this fact is often overlooked.
The second and third issues pertain to implementer knowledge of products on the market. Once an appropriate set of products have been chosen for the water source type, the implementer should be trained well enough to answer any questions about the products they recommend as well as answer any questions about products they do not recommend. In the study from Chapter 3, Jain encountered implementers so ill-prepared that they not only gave incorrect advice about water sanitation techniques such as boiling water, but in some cases they couldn't even answer questions about the products they were selling.

During the interview process, it would be wise of the implementers to make note of any cultural, religious, or habitual reasons for the improper use of the product. If the household was initially excited about the product, but upon receiving the product they didn't actually use it, observe why not. A product, while useful in one audience, may not be useful in another region if there are cultural stigmas countering its use. Understanding potential cultural or religious reasons as to why a group may not be using a product is valuable information for future implementers to know.

In addition to properly trained implementers, a support group for the users post implementation is important. Do the implementers come back to check in on the users after the initial purchase? Noting where a user can get assistance and support from the implementing group after their initial purchase is critical to the proper maintenance and use of the product.

Lastly, gathering all the information and documentation in a post-implementation review would be very useful for future efforts. Interviews with the implementers of the evaluation should also be conducted relatively soon after their experience so as to document it accurately. In addition to future efforts by other groups, a review would be useful for internal use to make sure that all persons involved are aware of the strengths and weaknesses of the evaluation system as it was executed.
Bibliography

