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Water Filters in Ghana: An Exploration of the Technology and Education that is Required for Sustainable Development at the Base of the Economic Pyramid

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Water Filters in Ghana: An Exploration of the Technology and Education that is Required for Sustainable Development at the Base of the Economic Pyramid

Abstract

In January of 2011 the authors volunteered to check up on a set of water filters that had been operating in a small village in central Ghana. The filters had been installed in the village by an interdisciplinary team of students and faculty from the United States and Ghana. The team had worked with the village leaders and families who received the filters to ensure the filters were used properly and maintained well. Unfortunately, after less than a year of operation, the authors were surprised to learn that the adding three drops of chlorine had become part of the standard monthly maintenance routine. Although chlorine is often used to kill harmful bacteria in water, adding chlorine to a sand filter may kill the beneficial bacteria that are vital to the operation of a sand filter. In addition there was no way to determine if the filter was working correctly. The authors inquired and discovered that the request to add the chlorine had come from a local science professor unfamiliar with the operating principles of a sand filter. The root cause of the problem is that the people using the filters did not have a functional understanding of how the filters worked. They lacked a conceptual model of the filter to guide their decisions about the water filter. Although it is not possible to give the users an in-depth understanding of how the filter operates, they must not be allowed to think of the technology as a black box because myths can grow up around technology that is not understood. Another barrier to the successful deployment of the sand filter technology is the fact that water filter technology does not provide any indication to the user of proper operation. Once set up the user has to trust that the filter is working properly. This paper uses the situation described to explore the appropriate education and features of the technology that can be employed to increase the likelihood that a development project will be successful and sustainable.

Introduction

The World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) have been working to reduce the number of people who rely on unimproved drinking water systems for the past 20 years. In their 2012 update on their work they reported encouraging progress however, they also reported that more than one tenth of the global population, or greater than 780 million people still relied on unimproved drinking water sources in 2010.[1] The home-sized biosand filter (BSF) developed by Dr. David Manz of the University of Calgary, is device that can be used to improve the quality and safety of drinking water.[2-4] A Biosand filters are small, household sized slow sand filters that have been adapted so that they can be run intermittently. The earliest biosand filters were introduced in the Nandaime Valley of Nicaragua as a pilot project in 1993.[5] The performance of the Nicaraguan filters and other filters around the world have been studied to determine their effectiveness at eliminating pathogens and other contaminates from water.[6] Other studies showed significant reduction in diarrheal disease associated with the use of BSF's.[7] In addition these studies found the biosand filter technology to be robust since those filters still in use were performing as expected three and eight years post implementation. However, Vanderzwaag found a low rate of sustained use, approximately 10%, and he attributed this to poor pre-installation education and a problem of the design that led the concrete BSF's to crack. This paper uses the author's experiences in Ghana and Nicaragua to explore different reasons for the low rate of sustained use. Until the causes of the low sustained usage rate for BSF's are identified and understood, the technology will not reach its full potential.

Biosand Filters

A biosand filter consists of a layer of gravel overlain with 2 layers of increasingly fine sand contained within a body or box made from either plastic or concrete. The body is usually three feet high with an internal or external standpipe. The standpipe rises up the wall of the structure to discharge at a point higher than the sand column, thus maintaining a standing depth of water in the filter. A diffuser is hung above the water level to prevent new water that is dumped into the filter from penetrating the upper sand level. Finally a cover is provided to prevent accidental contamination of the filter. A schematic of a BSF can be seen in Figure 1.

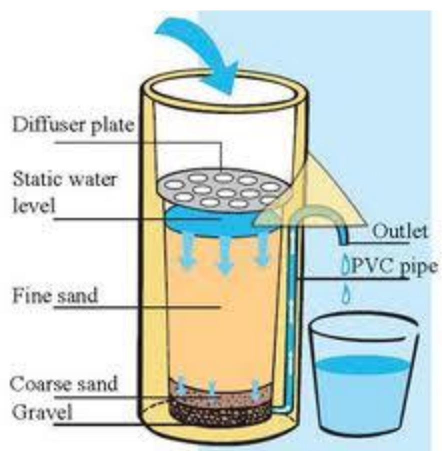

Figure 1. Components of a typical biosand filter. (Source: International Federation of Red Cross and Red Crescent Societies, 2008, *Household water treatment and safe storage in emergencies*)

The key to the operation of a BSF is the shallow layer of water sits atop the sand, where a biofilm, often referred to as a "schmutzdecke" (German for dirt covering) is created. This bioactive layer consists of algae, plankton and other microscopic plant life that helps reduce disease-causing organisms, particularly protozoa and bacteria. Waterborne pathogens that pass through this layer are removed through "inactivation (degradation and/or predation), physical straining, and attachment to the sand grains".[8] The fine layer of sand traps impurities, cysts and other bacteria. Biosand filters typically do not filter out contaminates in the water that are smaller than 40 microns and heavy metal contaminates like arsenic. After the BSF is assembled the user must wait approximately two weeks for the biological layer to form. Then the user can remove the lid, pour a bucket of water into the filter, and immediately collect the treated water in a clean container.

The Ghana Installation

In January of 2011 the authors volunteered to check up and perform maintenance on a set of water filters that had been operating in a small village in central southern Ghana called Atekyedo near the town of Winneba. Students from a mid-western comprehensive university raised the money to purchase 28 HydrAid™ BioSand Water Filters manufactured by Cascade Engineering of Grand Rapids, Michigan. The filters were installed in homes in the village in July of 2010. The students from the American university spent one day in the village assembling the filters and training the families who received the filters on their operation. The students worked with three Ghanaian University students familiar with the village to arrange logistics, translation and to ensure consistent follow-up. Although the operation of the filters was covered thoroughly in the one day training, the maintenance of the filters was not fully explained. To address this concern the installation team left language neutral instructions describing the maintenance procedures with each filter recipient.

At a planning session held the night before the authors visited the village, the authors were surprised to learn that the adding three drops of chlorine had become part of the standard monthly maintenance routine. The practice was not recommended by the installation team nor the instructions left with the villagers. Moreover, the practice had spread throughout the village. The authors feared that the chlorine could kill some or all of the microscopic plant life in the bioactive layer that are critical to the operation of the filter and thereby reduce the effectiveness of the filters. Upon further investigation, the authors learned that a professor from a local University had recommended the addition of chlorine. The problem was compounded by the fact that there was no way to quickly assess the how well the filter was operating. No one could tell the difference between a filter that was working well and one that was providing unsafe drinking water.

A Conceptual Model

After returning from Ghana the authors were troubled by the experience and search for the causes of these problems and how to prevent similar problems in the future. The authors identified the lack of a useful conceptual model of the filter and usability issues with the filter as the primary causes of the problem. A conceptual model is the way a user of a product believes the controls of the product are related to outputs of the product. "A good conceptual model of a product allows the user of the product to predict how their actions will affect the operation of the product." [9] No conceptual model was presented by the product or by the people leading the installation of the water filters. To the villagers the filter is a black box. Bad water goes in and good water comes out. They have a set of rules for maintenance and upkeep but do not understand purpose of the maintenance activities. When the filter behaves as expected a functional conceptual model is not needed. However, when an abnormal situation arises the villagers had no way to know the consequences of their actions. The authors can imagine that when a problem arose with the filters the villagers consulted a professor and he reasoned that the adding Chlorine to water is a common way to kill bacteria and therefore it would not harm and might even help the operation of the filter. In addition to being useful conceptual models must also be culturally and presented at the correct educational level. The development of a conceptual model that meets these requirements is difficult and is vest undertaken by an interdisciplinary team that includes members with deep knowledge of the technology and the target culture.

One possible conceptual model for the filter could be based on the idea of good germs and bad germs. Bad germs cause diarrhea and other ailments. Good germs help us digest food and sometimes prey upon bad germs. To reinforce these concepts the installation team could have used a simple microscope to show the villagers the germs in their water. Once these concepts were understood then a conceptual model of the filter could be built around these concepts. The conceptual model could be used to explain not only how the filter works, but also the maintenance instructions and the function of each part of the filter. For instance the existence of the diffuser can be attributed to the fact that if water is poured into the filter too quickly, some of the bad germs might not be eaten by the good germs in the bioactive layer and end up in the drinking water. Furthermore the requirement that the user wait two weeks after assembling the filter before drinking water from the filter can be attributed to the time the good bacteria in the bioactive layer need to grow strong enough to eat the bad germs. In this manner the conceptual model could be taught and reinforced. Then when something out of the ordinary happens, the users of the filters will have a better chance of correctly predicting the how the filters will react to any proposed changes. This is essential for the long term success of the filters or any new technology introduced.

Is the Filter Working?

The lack of a functional conceptual model is not the only problem with the implementation of the water filters in Ghana. The villagers had no way to determine if the water filter was working. The set-up instructions require the user to wait up to two weeks after setting up the filter before drinking water from the filter. The time is necessary for the bioactive layer to form. However, the villager has no way to verify that the filter is operating correctly. Some users of BSF's assume that if the visible particles in the water are removed then the filter is working properly. Unfortunately this is not a reliable method of evaluating filter performance. The lack of a reliable method to measure filter performance it impossible to know when to perform maintenance on the filter or when to seek another source of water this deficiency also contributes to the problem of the low rate of long term use discovered by Vanderzwaag in Nicaragua. To understand this phenomenon one must realize that the materials the used to make the filters can be used for many different purposes in an impoverished village. The authors have seen the remains of government issued sand filters used in numerous other applications in rural Nicaragua. If a villager does not know that the filter is working, they are more likely to disassemble the filter and use the parts for other purposes. The situation is exasperated by the relatively long time villagers must wait to enjoy the health benefits of clean water and the fact that drinking, even occasionally, from a tainted source of water can negate the benefits of drinking from a clean source of water.

Therefore, one method to improve the long term usage of the biosand filters would be to develop a simple and inexpensive test that the users of the filter could use to confirm that the filter is operating properly.

Conclusions

The problems of the water filters in Ghana reinforce two design principles that must be followed to successfully introduce a new product or technology. First the user must have a functional conceptual model of the technology to help them correctly predict how changes to the inputs of the product will affect the outputs of the product. Second, users must be able to easily obtain feedback from the product about the proper operation of the product. Without this feedback doubt about the correct operation of the product or technology may cause the user to abandon the technology. In the field of consumer product design these principles are well known. The authors experience with the water filters shows that the principles apply to products that will be used at the base of the economic pyramid.

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