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### ACCESS TO SANITATION AND SAFE WATER: GLOBAL PARTNERSHIPS AND LOCAL ACTIONS

# Characterizing the dissemination process of household water treatment systems in less developed countries

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*Recently, household-level water treatment and safe storage systems (HWTS) have been developed and promoted as simple, local, user-friendly, and low cost alternatives to conventional municipal-level drinking water treatment systems. Yet, despite conclusive evidence of the health and economic benefits of HWTS, the implementation outcomes have been slow, reaching only approximately 5-10 million people. This study attempts to understand the barriers and drivers affecting HWTS implementation. A review of existing literature on HWTS implementation found that existing research effort to promote HWTS is rather fragmented, with a narrow focus either on technical, psychological, or marketing perspective. Also, the application of innovation diffusion theories on HWTS implementation has been largely unexplored. To fill these research gaps, it is proposed that a system dynamics modelling approach to characterize the complex diffusion process of HWTS can be a valuable tool to identify high impact, leverage strategies to scale-up HWTS adoption and sustained use.*

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## 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 system 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, especially when implemented in rural regions. They include high per capita construction cost, poor water quality and 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).

Starting in the 1980s, simple household-level water treatment and safe storage systems (HWTS) have been developed and promoted by the scientific community and health authorities as viable alternatives to centralized water supply 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 (SODIS), ceramic filters, biosand filters, and flocculation-disinfection. 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 conclusive 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 disappointing. It is estimated only 5-10 million people uses HWTS on a regular basis, and there is not yet any successful large-scale implementation. Also, there are few indications that any HWTS strategies have provided sustained use over a long period of time (Lantagne et al., 2006; Murcott, 2006).

## Research objective

This paper describes a current research study which is investigating what the critical factors, barriers, and solutions to the introduction, adoption, scale-up, and sustained use of HWTS practices in developing countries are.

## Methods

This paper begins with an assessment and analysis of past research studies on the successes and failures of HWTS implementation. This is followed by a review of how innovation is diffused in society. Finally, limitations of the current research effort are identified, and recommendations are made to advance the understanding of HWTS implementation.

## Findings

### Current research efforts and limitations

A review of approximately 100 peer-reviewed journal papers and reports relating to HWTS reveals that the existing research effort to promote HWTS is rather fragmented, with a narrow focus either on technical improvement, behavioural change, or business marketing.

Studies related to technology research are usually conducted by researchers of engineering and public health disciplines. These studies often believe that improvements in the technical, health impact, and/or social characteristics of HWTS can give confidence to implementers, policy-makers, and end-users to promote, support, and use HWTS. As such, these studies are often designed to evaluate and/or to improve HWTS performance (Clasen et al., 2005; Brown, 2007).

Behavioural change related studies are often carried out by social scientists and psychologists. These studies generally assume that users' decision-making and behaviour to adopt and use HWTS are rational and predictable. Therefore, these studies often aim to identify factors affecting users' behaviour to adopt and use HWTS, and to evaluate the effectiveness of various social, psychological, and/or communication techniques to influence that behaviour. Some of the factors found to affect HWTS behaviour include knowledge, skills, attitude, beliefs, perceived risk/threats, habit, affect, self-efficacy, subjective norms, social pressure, and characteristics of the enabling environment (Fishbein and Ajzen, 1975; Moser et al., 2005; Kincaid and Figueroa, 2005).

Finally, studies related to business marketing are often conducted by researchers of business and/or management backgrounds. These researchers generally believe that conventional business entrepreneurship and the full range of marketing strategies to promote consumer products in western society can be effectively applied in developing countries to promote HWTS like any other commercial products (Kotler et al., 2002). Some of the strategies found to improve HWTS sales include situation analysis, marketing segmentation, and the 4 "P" (i.e. product, place, promotion, and price). Some studies also seek to uncover strengths, weaknesses, opportunities, and threats to the existing implementation strategies (Carpenter, 2003; Frey et al., 2006; POUZN, 2007).

While these studies uncovered important insight into factors affecting HWTS implementation, there are still gaps in the present research efforts. First the critical factors identified above may not be all the critical factors. There are still additional factors, such as political climate and human resources capability that are not fully understood. Second, there is rich literature on how various non-water innovations have been diffused in society in the past; yet, the application of these diffusion theories on HWTS implementation has been largely unexplored.

### Theories on innovation diffusion

In the early 1900s, Gabriel Tarde was among the earliest researchers to study how innovations are diffused in society. He noted that new technology adoption generally follows an S-shaped curve. In the 1940s, rural sociologists started to study the diffusion of ideas, concepts, and technologies, notably the adoption of hybrid corn among farmers in the American mid-west. Later, similar research was initiated in the public health, communications, marketing, geography, and other disciplines. Beginning in the 1950s, Everett Rogers, an American sociologist, compiled, integrated, and generalized findings from each of these diffusion research to form the basis of the classic theory on innovation diffusion, called the Diffusion of Innovations (DOI) theory. According to Rogers, diffusion of innovation is a process of which innovation is communicated through certain communication channels over time among the members of a social system (Rogers, 2003).

The major assumption of DOI is that novelty of an innovation will generate a sense of uncertainty in the potential adopter. Thus, diffusion of an innovation can be explained by a reduction in the perceived risk, which occurs through the communication process. The theory suggests that the innovations' perceived attributes (relative advantage, compatibility, complexity, trialability, observability), how the adoption decision is made, the characteristics of the communication channels, the nature of social system, and the extent of change agents' promotion efforts are the key critical factors predicting the rate of HWTS adoption. DOI explains that the decision to adopt an innovation happens in a series of five stages, starting at the knowledge stage, and

progressing to the persuasion stage, the decision stage, the implementation stage, and the final confirmation stage. The socio-economic status, personality values, and communication characteristics of each potential adopter determine how early or late he/she will adopt an innovation. Those who are financially better-off, well-respected, open to new values, and cosmopolite tend to adopt an innovation sooner than those who are less educated, traditional, and have less resources (Bass, 1969; Brown, 1981; Rogers, 2003).

Although DOI provides excellent explanations on why diffusion occurred, DOI is a descriptive theory built upon hindsight of successfully diffused innovations. The theory is weak in its predictive power to forecast future adoption patterns, and cannot explain why some innovations fail to diffuse. Also, DOI lacks insight into the complexity and the inter-connectedness of the components affecting HWTS adoption. DOI treats the rate of adoption as a function of the critical factors as in a black box, without accurately explaining how the independent and dependent variables are related, nor to provide guidance as to how to accelerate the rate of adoption. Furthermore, DOI is criticized for its blame on an individual for their slowness in adopting an innovation. Their lack of knowledge and familiarity of an innovation is assumed to have held back diffusion (Deshpande, 1983; Haider and Kreps, 2004).

Besides the DOI, the diffusion process of an innovation in society may also be explained by four other perspectives. In contrast to the demand-side bias of the DOI, *economic history perspective* of diffusion pays attention to the role of supply-side actors in diffusion. This perspective assumes that potential adopters are rational economic agents; therefore, improvements in a technology's performance, and decreases in cost are the key drivers for diffusion (Rosenberg, 1972; Brown, 1981).

The *development perspective* assumes that potential adopters in society have unequal access to the resources required for adoption. As such, the adopters' purchasing power and the processes that enhance or reduce that power are the key determinants to the diffusion process. This perspective has particular strong support to explain diffusion in many developing countries where the distribution of resources is highly stratified, and the cost to adopt an innovation is prohibitive expensive for the vast majority of the population (Harrison, 1994).

The *market infrastructure perspective* assumes that the adoption of an innovation is constrained by its availability. As such, when opportunity to adopt becomes available, diffusion will occur. One major implication of this perspective is that a large amount of variance in spatial patterns and temporal rates of diffusion can be explained by institutional behaviour, rather than by individual behaviour. Potential adopters will not have the option to adopt unless governments, businesses, or other change agencies make the innovation available at locations accessible them (Brown, 1981; Miller and Garnsey, 2000).

Finally, the *entrepreneur perspective* assumes that the mismatch between supply and demand can hinder the diffusion process. Therefore, the capacity of entrepreneurs to successfully match resources and opportunities can strongly influence the rate of technological innovation diffusion in society (Miller and Garnsey, 2000).

### **System dynamic modelling tool**

At this moment, a wide variety of critical factors from multiple disciplines and frameworks has been found to affect the HWTS diffusion process. Confronted with this perplexing and ever-expanding list of factors, it can be very challenging to comprehend and operationalize the above findings in order to develop any successful promotion strategies. Therefore, it is very important to employ an integrating and simplifying tool to guide HWTS researchers to make proper analysis, and to aid policy-makers to make sound decisions. Rather than randomly adhering to a few critical factors and hoping for a successful implementation, a holistic and systematic understanding of the interdependency of these factors to clarify the complexity and non-linearity of the HWTS diffusion process can prove to be a more powerful problem solving approach.

Of the different tools available, system dynamics modelling appears to be one of the most useful. Initially developed at Massachusetts Institute of Technology in the 1950s as a technology management tool, system dynamics modelling is an instrument highly suitable for characterizing and clarifying complex systems, in order to analyze the effectiveness of different intervention strategies to promote adoption and sustained use of HWTS (Forrester, 1961; Sterman, 2000).

Figure 1 shows an example of a simple system dynamic model of HWTS adoption and sustained use. In this model, the population is divided into three groups, namely potential adopters, current adopters, and discontinued population. The potential adopters can be converted to current adopters through either advertisement or word-of-mouth influences from current adopters. Current adopters may discontinue using HWTS after some time, perhaps due to dissatisfaction of the HWTS performance, or due to breakage or

other factors. For illustrative purpose, the model assumes that the advertisement is effective to convert 2% of the potential adopters to become current adopters per month. The model further assumes that the proportion of potential adopters converting from word-of-mouth effect is equal to 1/10 of the ratio of adopters to the total population of 10,000 people. The drop off rate is assumed to be 10% of the current adopters per month. Figure 2 shows the simulated results.

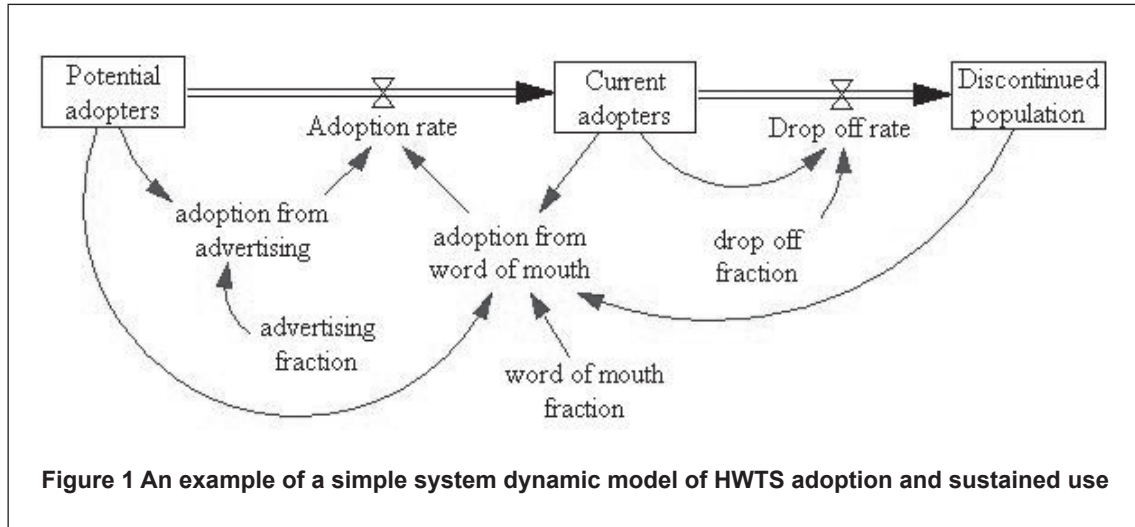
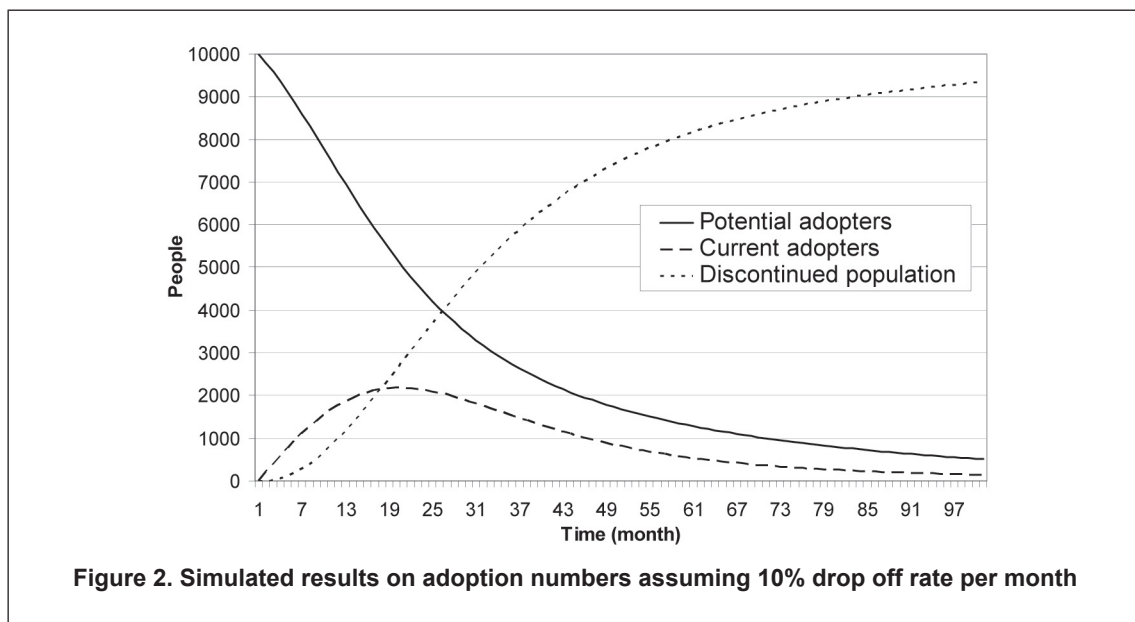


Figure 2 shows that in the initial months, potential adopters are converted to current adopters, as shown by the decline in the number of potential adopters. The number of current adopters increases to a maximum of about 2200 people around month 20, and then decreases gradually to less than 200 by the end of the simulation at month 100. The main reason for the low number of current adopters at any given time seems to be that adopters are quickly dropping out of HWTS usage, as shown by the rapidly rising discontinued population curve.

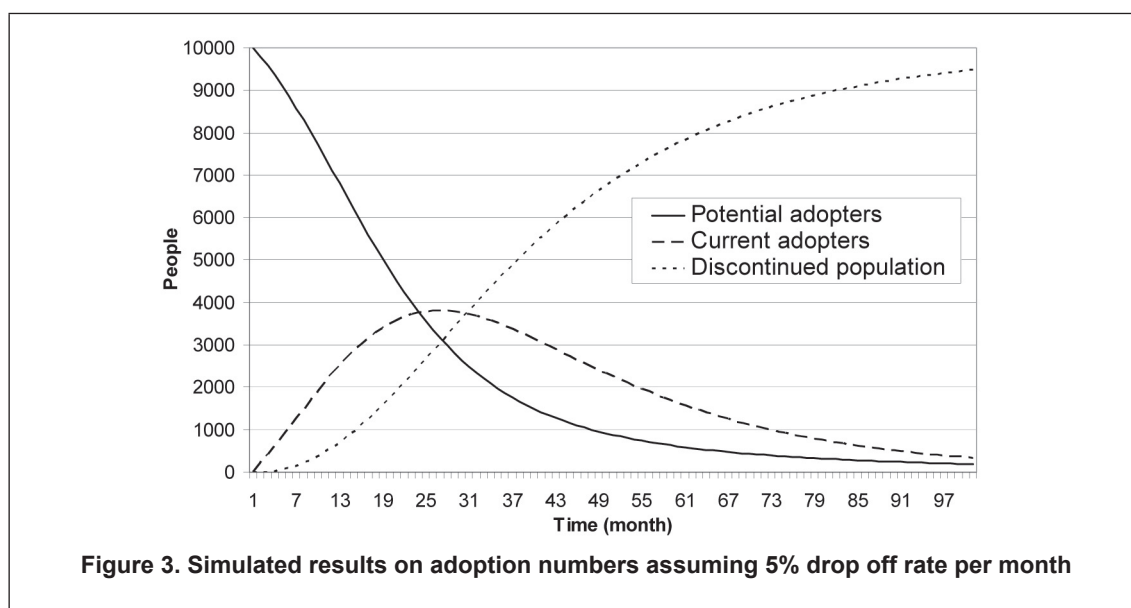


To further explore the effect of drop off rate, the model is simulated again using the same values for the model parameters, except that the drop off rate is reduced to 5% per month. Figure 3 shows the simulated results. In this scenario, the most observable difference is that the maximum number of current adopters is increased to about 3800 at around month 25, and drops to about 300 by month 100. This is a remarkable improvement over Figure 2 results. However, a less apparent outcome is that the potential adopters curve drops

quicker than in Figure 2. It is because as the number of current adopters increases, the word-of-mouth effect increases as well, which generates greater adoption rate, and pulls down the potential adopters curve.

By comparing the results of Figure 2 and Figure 3, one potential policy implication is that increasing the rate of sustained use can be an effective method for HWTS scale-up. Not only does this strategy reduce the “loss” of current adopters, but this strategy can also indirectly increase adoption rate through enhanced word-of-mouth effect.

However, it should be noted that the above simulations are for illustrative purpose only. The model has many simplifying assumptions that may not be valid in actual situation. For example, the diffusion process is assumed to be governed by the reduction in the perceived risk of HWTS, which occurs through the communication process of advertising and word-of-mouth (i.e. the DOI perspective), as opposed to a diffusion process driven by other perspectives. The current adopters drop off rate is assumed to be a fix ratio applied homogeneously across the entire population, ignoring individual differences in adoption and drop off behaviour, and disregarding users who may continue to practice HWTS indefinitely. Furthermore, the model behaviour can be highly sensitive to the values of the parameters, such that these values should be calibrated with actual data before it can be concluded that such policy is indeed useful.



### Conclusions and future directions

Therefore, the next step in this research is to build actual system dynamics models to understand the complex HWTS diffusion processes for six HWTS projects, selected from Asia, Latin America, and Africa. To do so, the first step is to identify what the key critical factors are, obtained by methods such as site observations, personal interviews, group interviews, review of relevant project documents. Then, these key critical factors will be integrated into project specific models showing the inter-relationship of these critical factors, taking into consideration the local context and situation. Next, models will be calibrated and tested against historical trends to evaluate the model parameters accuracy. Factors and parameters found to be highly influential to the model behaviour by sensitivity analysis technique will be further verified to confirm their accuracies. It is expected that such grounded models can provide new yet practical approach to policy-makers, government officials, field practitioners, international donors, and researchers to identify high impact, leveraged policies to quicken the HWTS diffusion process. Also, comparisons of different models and their respective policy implications may yield further insight into whether HWTS dissemination process is project/regionally specific, or can be generalized for worldwide application.

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