Factors from Diffusion of Innovations Theory Influencing the Adoption of Solar Water Disinfection: A Field Study in Bolivia

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Zürich, Mai 2006
Abstract

In this study we examine a broad array of theory-based factors derived from diffusion research that influence the current use and intention to use of solar water disinfection (SODIS), a simple, low-cost technology for the treatment of drinking water on household-level. The perceived attributes of an innovation, the nature of the social system in which an innovation is diffused, the extent of change agents’ promotion efforts in diffusing the innovation and the nature of the communication channels were operationalized resulting in 16 variables to assess the use and intent to use of the innovation of SODIS. The aim of the study is to determine the influence of each factor and its predictive power. Eight areas in Bolivia were visited and 644 families interviewed on the basis of a structured questionnaire. Results generally confirmed the hypothesized relationship between independent and dependent variables, thus supporting our guiding theory of diffusion research. Simultaneous multiple regression analysis showed that nine of the 16 factors derived from diffusion research contributed significantly to prediction of the current use of SODIS the most influential one being the percentage of safe drinking water without the one treated with SODIS consumed. Whereas the intention to use SODIS in the future was significantly predicted by 10 factors the most influential one being the affective beliefs. The implications of the findings for tailoring future SODIS diffusion activities are outlined.

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1. Introduction

The World Health Organization (WHO, 2005) estimates that currently 1.1 billion people, which represents 17% of the global population, lack access to improved water sources\(^1\). The dramatic consequences are that 1.8 million die every year from diarrhoeal diseases; 90% are children under five years of age, mostly in developing countries (Kosek, Bern & Guerrant, 2003; Prüss, Kay, Fewtrell & Bartram, 2002). Eighty-eight percent of diarrhoeal disease is attributed to unsafe water supply, inadequate sanitation and hygiene. Universal access to safe water and sanitation is an essential step in reducing this preventable disease burden. The Millennium Declaration adopted by the United Nations General Assembly in 2000 established the lesser but still ambitious goal of halving the proportion of people without sustainable access to safe drinking water and basic sanitation. All 191 United Nations Member States have pledged to meet the Millennium Development Goals (MDGs) by 2015, and the United Nations General Assembly (2003) has given the water supply MDG additional weight by declaring 2005-2015 to be the International Decade for Action Water for Life.

In order to meet the water supply MDG target, an additional 260 000 people per day up to 2015 would have to gain access to improved water sources (WHO, 2005). Relying only on time- and resource-intensive centralized solutions such as piped, treated water will leave hundreds of millions of people without safe water far into the future. Moreover, some of the 83% of the world’s population who use improved water sources nonetheless drink water that has been contaminated. The water quality in systems classified as improved water supply is often affected from unreliable operation and lack of maintenance, or the water is subject to secondary contamination during collection, transport, and storage.

For these segments of the world’s population, decentralized point-of-use water treatment systems have direct beneficial effects in the form of reduced infectious diseases. In a

\(^1\) The following technologies are regarded as improved water sources: Piped water into dwelling, yard, or plot, public tap/standpipe, tubewell/borehole, protected dug well, protected spring, rainwater collection (WHO/UNICEF, 2005, p. 6).
recent review and meta-analysis Fewtrell, Kaufmann, Kay, Enanoria, Haller & Colford (2005) came to the conclusion that point-of-use water treatment systems are even more effective than has been previously acknowledged and lead to a reduction of diarrhoea episodes by 39%. The technologies included in the meta-analysis were chemical treatment, boiling, filtration, pasteurisation, and solar water disinfection.

Although point-of-use water treatment is an effective and useful approach applicable in many circumstances, it shifts the burden of treatment away from centralized systems to individual households where day-to-day behaviour is often hardest to change. Therefore, according to a report from the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (2005), questions of acceptability and long-term use have yet to be addressed.

In this article we focus on the innovation of solar water disinfection with the purpose to gain insights into which are the most important factors that influence the use of solar water disinfection. In order to answer this question, we draw on Rogers’ (2003, original edition 1962) theory of diffusion of innovations and apply its framework to explore the use and intention to use of solar water disinfection in eight areas of Bolivia with different exposure to diffusion activities, different levels of urbanisation and different geographical conditions. Given the estimated number of no more than 47% of the people in rural and 92% in urban areas of Bolivia with access to a household connection (WHO/UNICEF, 2004) combined with a high prevalence of diarrhoea, especially among children under 5 years of age (Instituto Nacional de Estadistica de Bolivia, 2003) there seems to be a need for fast and simple water treatment solutions. Furthermore, with the Fundación SODIS, based in Cochabamba, Bolivia and in charge of supporting the implementation of SODIS in Latin America, we had a strong local partner whose support in the field data collection was paramount.
2. Theory

2.1. Solar Water Disinfection

Treatment of water with solar radiation was practiced in ancient India more than 4000 years ago (WHO, 2002). The ability of solar radiation to disinfect has been recognized in modern times at least since studies by Acra, Raffoul & Karahagopian (1984) at the American University of Beirut. In 1991 an interdisciplinary team from the Department of Water and Sanitation in Developing Countries (SANDEC) at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) embarked on extensive laboratory and field tests to assess the potential of solar water disinfection (SODIS). A simple, low-cost technology to improve the microbiological quality of drinking water through solar radiation and thermal treatment was developed: Contaminated water is filled into transparent Polyethylenterephthalat (PET) bottles and exposed to full sunlight for six hours (or for two consecutive days if the sky is more than 50% cloudy). Sunlight is inactivating and destroying pathogenic micro-organisms which cause water-borne diseases through two synergetic mechanisms, radiation in the spectrum of UV-A (wavelength 320-400nm) and increased water temperature (Meierhofer & Wegelin, 2002).

Laboratory studies of SODIS have demonstrated significant reductions in bacterial contamination (Wegelin, Canonica, Mechsner, Fleischmann, Pesaro & Metzler, 1994; McGuigan, Joyce, Conroy, Gillespie & Elmore-Meegan, 1998). Previous field trials under controlled conditions among a nomadic Maasai population in Kenya resulted in promising findings (Conroy, Elmore-Meegan, Joyce, McGuigan & Barnes, 1996, 1999) including cholera infection risk reduction (Conroy, Elmore-Meegan, Joyce, McGuigan & Barnes, 2001). A research project implemented by the Swiss Tropical Institute in a rural area of Mizque, Bolivia, has shown that SODIS significantly reduces diarrhoea incidence by 10 to 55% (Hobbins, Indergard & Mäusezahl, 2004). Most recently, Rose et al. (2006) found in a field evaluation in
southern India that the use of SODIS significantly decreased diarrhoea in children less than five years by over 40%. SODIS is well documented in homepages (e.g. www.sodis.ch, www.fundacionsodis.org) and a variety of different training and promotion material such as leaflets, posters, manuals, and videos are available for dissemination purposes. Given the straightforwardness of the technology and the need for only transparent PET-bottles as well as the serious health threats from diseases caused by waterborne pathogens, it is not evident why SODIS has encountered a rather slow and limited uptake in some areas. In order to gain insight into this discrepancy we employed Rogers’ (2003) theory of diffusion of innovations with the aim to determine the most important factors influencing the adoption of SODIS and the intention to use SODIS in the future.

2.2. Theory of Diffusion of Innovations and its application to SODIS

Rogers (2003) posits that the adoption of an innovation is affected by (a) the perceived attributes of the innovation (b) the type of innovation-decision, (c) the nature of the social system in which the innovation is diffused, (d) the extent of change agents’ promotion efforts in diffusing the innovation, and (e) the nature of communication channels. These five types of variables that determine the adoption of an innovation have not received equal attention from diffusion scholars. The perceived attributes of an innovation have been most extensively investigated (e.g. Darley & Beniger, 1981; Moore & Benbasat, 1991; Tornatzky & Klein, 1982). However, as Rogers (2003) notes, only little research (e.g. Völlink, Meertens & Midden, 2002) had been carried out to determine the relative contribution of each of the five types of variables. With the exception of the type of the innovation-decision that is not applicable to this study because SODIS is a household water treatment technology and therefore adoption occurs by definition on household-level, we describe in the following the factors we derived as possible determinants of the use and intention to use SODIS.
2.2.1. Attributes of the Innovation

The first factor, attributes of the innovation, is the most widely studied one (e.g. Moore & Benbasat, 1991). Five attributes have been found to explain between 49 and 87 percent of variance in the rate of adoption of innovations. These are (a) the relative advantage of the innovation over the idea it supersedes, (b) compatibility with the existing values, past experience and needs of the receivers, (c) complexity, or the degree to which the innovation is perceived as difficult to understand and use, (d) trialability, or the degree to which an innovation can be tested for effectiveness on a cost or scope-limited basis, and (e) observability of the outcome of the innovation (Rogers, 2003). These dimensions are psychological ones in that the individual’s perceptions of the attributes of an innovation rather than its objective attributes determine the innovation decision of the potential adopter. Ostlund (1974) found that these five dimensions were much better predictors of innovation acceptance than were the personal characteristics of respondents (education, income, cosmopolitanism, etc.) usually employed in diffusion research. Even though there is evidence that variables such as socio-economic status, gender, ethnicity and age affect the extent to which people would adopt preventive health behaviour (Rosenstock, 1974), for example the treatment of drinking water, these can not be modified through health education. Effective health intervention depends upon identifying modifiable psychological characteristics such as the perceived attributes of an innovation. In the following sections the five perceived attributes of SODIS as an innovation are elaborated in more detail.

The relative advantage is the degree to which an innovation is perceived as better than the idea that it supersedes. With regard to SODIS, the enhanced safety of the drinking water is the most obvious relative advantage that may be perceived by potential adopters. Further, cost savings (e.g. compared to the costs of boiling water) and the sometimes reported better taste of the SODIS-treated water might be perceived as relative advantages. The latter is due to the unchanged level of oxygen dissolved in the water compared to the decrease of it during the
boiling process and as well as, depending on local water quality, the growth of (harmless) algae in SODIS bottles during prolonged solar exposure. Therefore, the more a person perceives the relative advantages of SODIS as measured in (a) cost-savings, (b) better taste and (c) enhanced safety of the drinking water, the more he or she may be inclined to use and intent to use SODIS in the future.

Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. Compatibility was conceptualised on four dimensions, (a) the compatibility of the application of SODIS with the daily tasks and habits, (b) the cognitive beliefs towards SODIS, (c) the affective beliefs towards SODIS, and (d) the perceived threat of diarrhoea. In accordance with the findings of Tractmow & Sheeran (1998) indicating that items measuring affective and cognitive beliefs towards behaviours loaded on separate dimensions, we drew a distinction between cognitive and affective beliefs about SODIS. The cognitive dimension evaluated the confidence that is placed in the technology of SODIS as a safe drinking-water treatment whereas the affective belief evaluated whether the use of SODIS is perceived as pleasant or unpleasant. In order to assess to what degree diarrhoea is perceived as a health threat in the cultural context of our sample, two variables forming the perceived threat of diarrhoea from the protection motivation theory (Rogers, 1983) were recorded. These were estimates of the chance of contracting diarrhoea (i.e. perceived vulnerability) and estimates of the seriousness of diarrhoea (i.e. perceived severity). The key to understanding threat assessment is its perceptual nature regardless of the true incidence of threat in the population. The messages sent by public health officials, for example, are not necessarily sensed by the individual. Furthermore, if sensed, these messages may be distorted by perceptual processes (Kirscht & Rosenstock, 1979). Originally, perceived severity and vulnerability were hypothesised to be combined multiplicatively to arouse protection motivation (Rogers, 1975). This combinatorial rule, however, failed repeatedly to receive empirical support and in a revised version of the theory, Rogers
(1983) rejected the multiplicative combinatorial rule in favour of an additive model. Hence it is hypothesized that the more a person perceives the compatibility of SODIS as measured in (a) compatibility with daily tasks and habits, (b) confidence in the technology (i.e. cognitive beliefs), (c) the degree to which the application of SODIS is perceived as pleasurable (i.e. affective beliefs) and (d) the perceived threat of diarrhoea the more he or she may be inclined to use and intent to use SODIS in the future.

Complexity is the degree to which an innovation is perceived as relatively difficult to understand and to use. Any new idea is classified by the potential adopters on the complexity-simplicity continuum (Rogers, 2003). Given the straightforwardness of SODIS, complexity may not be as important as the other attributes, however, Perceived difficulty can be a strong barrier to the adoption of an innovation. Therefore it is hypothesized that the more a person perceives it as difficult to understand and use SODIS, the less he or she may be inclined to use and intent to use SODIS in the future.

Trialability is the degree to which an innovation may be experimented with on a limited basis. The personal trial of an innovation is one way for an individual to give meaning to an innovation and to find out how it works under one’s own conditions. Little resources are needed for the correct application of SODIS. However, to experience a reduction in the diarrhoea rate it is crucial that the trial phase can be sustained over an extended time period. Therefore, we measured trialability by means of the perceived availability of the resources necessary to apply SODIS on a regular basis. These are essentially the sufficient availability of sunny surfaces to place the bottles, sufficiently clear water, and an adequate supply of transparent PET-bottles to treat as much water with SODIS as needed. Thus, it is hypothesized that the more a person perceives the sufficient availability of the resources essential to

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2 As radiation intensity is reduced by increasing turbidity, raw water of low turbidity (< 30 Nephelometric Turbidity Units) should be used for SODIS. A simple method to assess water turbidity is available at http://www.sodis.ch/files/note7.pdf
try SODIS over an extended period as measured in (a) sunny surfaces (b) clear water and (c) PET-bottles, the more he or she may be inclined to use and intent to use SODIS in the future.

Observability is the degree to which the results of an innovation are easily observed by and communicated to other people. Preventive innovations, defined as new ideas that an individual adopts now in order to lower the probability of some unwanted future event, such as SODIS, sometimes have a particular slow rate of adoption because individuals have difficulties in perceiving its observability (Rogers, 2002, 2003). Adoption by an individual now may prevent getting diarrhoea in some future time. But the individual might not have contracted diarrhoea even without adopting the idea of SODIS. Hence not only are the rewards of adoption delayed in time, but it is uncertain as to whether they are actually essential. The unwanted event that is avoided by adopting a preventive innovation is difficult to perceive because it is a non-event, the absence of something that otherwise might have happened (cf. Singhal & Rogers, 2003). Hence, it is hypothesized that the more a person perceives observability of the results of SODIS as measured in subjective reduction of diarrhoea episodes, the more he or she may be inclined to use and intent to use SODIS in the future.

2.2.2. Social System

Diffusion occurs within a social system. A system’s norms can facilitate or impede the diffusion of innovations. When considering normative influence from the social system on behaviour it is crucial to discriminate between injunctive norms, that specify what ought to be done, and descriptive norms, that specify what is done (Cialdini, Reno & Kallgren, 1990; Rhodes & Courneya, 2003). The injunctive meaning of norms refers to rules or beliefs as to what constitutes morally approved and disapproved conduct. The descriptive norm describes what is typical or normal. It is what most people do, and it motivates by providing evidence as to what will likely be effective and adaptive action. Thus, it is hypothesized that the stronger
a person perceives the injunctive norm and descriptive norm to be in favour of SODIS, the more he or she may be inclined to use and intent to use SODIS in the future.

2.2.3. Extent of Change Agents’ Promotion Efforts / Communication Channels

The adoption of an innovation is as well affected by the extent of change agents’ promotion efforts. A change agent is an individual who influences clients’ innovation-decisions in a direction deemed desirable by a change agency (Rogers, 2003). Three different types of communication channels for change agents’ promotion strategies had been used in our investigation areas. The first type was household visits, performed by staff of the SODIS Foundation, by staff of the partner NGOs, by local authorities or by volunteers of the local health centre. A second type of communication channels was official events such as health fairs, presentations in community assemblies, women’s groups or mothers’ centres and activities in schools. The third type was the use of mass media such as radio or television transmissions, advertisements in newspapers or with posters as well as the distribution of promotion materials like stickers and calendars. We hypothesized that the number of strategies actively participated in is positively related to the use and intention to use of SODIS.

2.2.4. Percentage of Safe Drinking Water on Total Consumption of Liquids That is not Treated With SODIS

The main criterion for judging the relative success of diffusion intervention is usually the rate of adoption of an innovation that they achieve. In some cases, however, this measure of change agency effectiveness needs to be seriously questioned (Rogers, 2003). An alternative measure of change agent’s success might be the degree to which the desired consequences of innovation adoption actually occurs to clients. Also, the quality and sustainability of adoption
decisions resulting from a diffusion campaign may be more important than just the number of adoptions achieved in a certain time period.

With regard to change agency effectiveness and its measure, it is important to note that SODIS is introduced as a complementary water purification technology replacing raw water consumption. Thus, the aim of its implementation is defined as to accumulate a large number of SODIS users without rejecting already existing water disinfection habits (Soto, 2004a). To take this implementation message into consideration it was essential to introduce a factor controlling for the percentage of safe drinking water on the total consumption of liquids that is not treated with SODIS but with another water treatment method or bought bottled in a store and thus can be regarded as safe. Therefore, it is hypothesized that the higher a person's percentage of the safe drinking water consumed that is not treated with SODIS (e.g. by boiling, buying drinks), the less he or she may be inclined to use and intend to use SODIS in the future.

2.2.5. The current use of SODIS and the intention to use SODIS in the future

The adoption of the innovation of SODIS is conceptualized as the current use of SODIS-treated drinking water. Moreover, the intention to use SODIS in the future was taken as a discrete variable with the aim to explore determinants of the continued use of SODIS. Behavioural intentions are seen as a key ingredient in many health behaviour models. Several of these theories, notably the theory of reasoned action (Fishbein & Ajzen, 1975) and the theory of planned behaviour (Ajzen, 1991), postulate a strong relationship between intention and behaviour, such that intention is the strongest predictor of behaviour. Therefore, most empirical studies based on these theories measure intention of behaviour, not both. Armitage & Conner (2001) found in a meta-analysis that of the 163 studies included, only 63 actually assessed both intention and behaviour. Instead, intentions serve often as a proxy for the behaviour. Such substitution makes the assumption that if a given individual states an inten-
tion, the corresponding behaviour will not differ systematically from this intention. However, even though intentions do correlate highly with behaviours (Ajzen, 1991), there remains a fundamental issue that intentions do not always translate into the health behaviour (e.g. Godin & Kok, 1996; Johnston & White, 2003; Sheeran, 2002).

Because in this project only one visit to each of the 644 households was scheduled, this lead us to evaluate the current behaviour and the intention regarding future behaviour at the same point in time. Consequently the intention does not affect the evaluated behaviour. However, to understand the acceptability of the long-term use of SODIS and to improve activities to promote it, the intention to use SODIS in the future was judged to be the best measure available.

2.2.6. Summary of Hypotheses

We posit that individuals are the more likely to use and intent to use SODIS in the future, the more they perceive that (a) SODIS has a relative advantage in terms of cost savings (cost savings), (b) better taste (taste of water), and (c) enhanced safety (safety of water), (d) SODIS is well compatible with their daily tasks and habits (daily tasks and habits), (e) the application of SODIS is pleasurable (affective beliefs), (f) that they have confidence in the technology of SODIS (cognitive beliefs), (g) the threat of diarrhoea is considerable (threat of diarrhoea), (h) there are enough sunny surfaces available to apply SODIS correctly (sunny surfaces), (i) they have enough sufficiently clear water at their disposal (clear water), (j) they have enough PET-bottles available to prepare as much SODIS-treated water as they need (transparent bottles), (k) the results of SODIS are observable (experience of reduction in diarrhoea episodes), (l) the injunctive norm favours SODIS (injunctive norm), (m) the descriptive norm favours SODIS (descriptive norm), and individuals are more likely to use and intent to use SODIS (n) the more diffusion strategies they participated actively in (number of strategies participated). Further, we posit that individuals are less likely to use and intent to use SODIS (a) if they believe
that SODIS is difficult to use correctly (perceived difficulty), and (b) the bigger the percentage of safe drinking water without SODIS on their total consumption of liquids is (percentage of safe drinking water without SODIS). The aim of this study is to determine the predictive power of each of these factors derived from diffusion research in a large and varied sample from eight areas of Bolivia. This theory-guided approach could provide a framework for developing theory-based SODIS diffusion programs that address relevant predictors.
3. Method

3.1. Participants and Procedures

Participants ($N = 644$) were from eight areas of Bolivia that were selected for this study because of their diversity. Criteria were different geographical conditions (valley, highlands, lowlands), different levels of urbanisation (peri-urban, rural), the duration of the projects and different implementing agencies (NGOs, government entities). Table 1 displays an overview about the characteristics of the investigation areas in regard to selection criteria. Projects differ in regard to the number, combination, and length of the strategies they applied as well as in their general focus. For example, the project in Villa Tunari started only a couple of months before our investigation took place and the main focus was not the promotion of SODIS but medical aid for remote communities. The project in the neighbourhood of San Pedro in Potosí started already 1999, whereas in the neighbourhood of San Gerardo, no active diffusion strategy at all took place.

Table 1

<table>
<thead>
<tr>
<th>Department</th>
<th>Alto Sebastian Pagador</th>
<th>Tiraque</th>
<th>Yapacani</th>
<th>Potosi (San Pedro)</th>
<th>Potosi (San Gerardo)</th>
<th>Uncía / Llallagua</th>
<th>Caripuyo</th>
<th>Villa Tunari</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communities visited</td>
<td>Neighbourhood of Alto Sebastian Pagador</td>
<td>Chaqo</td>
<td>Tora Lapa</td>
<td>Baja Piñata 15 de Octubre Parra Rancho</td>
<td>Neighbourhood of San Pedro</td>
<td>Neighbourhood of San Gerardo</td>
<td>Jachasi Juyo</td>
<td>Lawa Lawa</td>
</tr>
<tr>
<td>Geographic location</td>
<td>Valley</td>
<td>Valley</td>
<td>Lowland</td>
<td>Highlands</td>
<td>Highlands</td>
<td>Highlands</td>
<td>Highlands</td>
<td>Lowland</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Peri-urban</td>
<td>Rural</td>
<td>Rural</td>
<td>Peri-urban</td>
<td>Urban</td>
<td>Rural</td>
<td>Rural</td>
<td>Rural</td>
</tr>
<tr>
<td>Number of households interviewed</td>
<td>80</td>
<td>80</td>
<td>87</td>
<td>80</td>
<td>80</td>
<td>76</td>
<td>81</td>
<td>80</td>
</tr>
</tbody>
</table>
A Bolivian interviewer team collected all data through structured interviews in July and August 2004. The interviewer team was trained and supervised by the author of this study, Moser (2005), and a Bolivian master student together with professionals from the Fundación SODIS. To exclude cultural and linguistic misunderstandings the questionnaire was revised by professionals of the Fundación SODIS, a Bolivian master student and the interviewer team, who also jointly translated the questionnaire from Spanish to Quechua. The applicability of the questionnaire as well as the interviewers’ performance after a one-week training course were tested in a pretest in Lagunitas, a rural community in the geographical area of the valley.

Our arrival in the respective investigation areas was preceded by arrangements with the local partner organisations and authorities to facilitate the first contact with the households and to provide local guidance to reach the often remote communities. All households willing to participate were interviewed in the rural communities. In the peri-urban and urban areas participants were selected by the random route method (Hoffmeyer-Zlotnik, 1997). Streets within neighbourhoods were randomly sampled, and every third house on sampled streets was approached. Consent was obtained before starting the interview. At the end of the questionnaire the participants were encouraged to ask questions and to comment on the interview and the topic of water and SODIS in general. Incentives were employed to yield a high participation rate. After the conclusion of the interview each participating household was offered a small gift pack consisting of cooking oil, rice, and soap.

Interviews were held with the person responsible for drinking water in the respective household; this person was female in 80% of the interviews. According to the participants’ preference interviews were conducted in Spanish (53%) or Quechua (47%). The medium age of the adult persons living in the interviewed households was 35.9 years ($SD = 11.2$) and the medium years of education 5.3 ($SD = 3.5$) with a higher average in the urban and peri-urban areas ($M = 7.2, SD = 3.7$) than in the rural ones ($M = 4.1, SD = 2.8$).
The average household size was 5.1 ($SD = 2.5$) persons and the mean of children under the age of five per household was 0.9 ($SD = 1.2$) [why is this information important?]. The occupation of 43% of our sample was homemaker, 25% worked in agriculture, 8% held a formal employment, 4% were from self-employed professions, 8% worked in the informal sector, 1% stated being without any occupation and 11% held some other occupation, mostly they were enrolled in college, university or further education.

The water source was piped water into dwelling, yard or plot in 61% of the households interviewed, 23% obtained their drinking water from wells, 4% from rivers or streams, and for 12% of the households interviewed, water was delivered by water tank trucks.

### 3.2. Questionnaire

The questionnaire was designed to obtain measures of the various factors to be inspected. Except from three variables calculated in percentages, all variables used Likert-type formats (e.g. *very safe* to *very unsafe*). As Likert scales with different numbers of categories had been applied all items were $z$-transformed.

#### 3.2.1. Independent Variables

3.2.1.1 Attributes of the Innovation

Rogers (2003) emphasised that the specific ways in which the five attributes are expressed differs in each study and that therefore the measures of these attributes should be uniquely created afresh in each investigation rather than utilizing existing scales borrowed from previous investigations. The relative advantage of SODIS was measured on the three dimensions of cost savings, taste of the water, and water safety enhancement. Participants had to assess un-
treated, SODIS-treated and boiled water from 1 (*not cost-saving/safe/taste*) to 3 (*very cost-saving/safe/tasty*).

To measure the compatibility of the application of SODIS with daily tasks and habits, participants were asked to what extent the application of SODIS fits smoothly into their usual day-to-day habits and answers were categorised ranging from 1 (*lowest compatibility*) to 7 (*highest compatibility*). Cognitive beliefs about SODIS were recorded by asking as to what extent participants have confidence that the SODIS-treated water is safe to drink. Answers were marked on a scale from 1 (*no confidence, completely unsafe*) to 4 (*full confidence, completely safe*). Affective beliefs were operationalized by enquiring whether the application of SODIS is perceived as enjoyable or rather disturbing, answers were marked from 1 (*not enjoyable at all*) to 7 (*very enjoyable*). Perceived health threat of diarrhoea is an additive combination (Rogers, 1983) formed by perceived vulnerability and perceived severity. The vulnerability to contract diarrhoea was assessed by asking about the participants’ perceived likelihood to contract diarrhoea when drinking untreated water, answers were categorised from 1 (*very unlikely*) to 7 (*very likely*). In order to assess the perceived severity of diarrhoea, participants were asked as to what extent they perceive their health affected when they suffer from diarrhoea, answer categories ranged from 1 (*not severe at all*) to 5 (*very severe*). Items were z-transformed before being combined additively into the perceived threat of diarrhoea as described in the theory section.

Complexity was measured by asking whether participants perceive the correct application of SODIS as difficult. Answers were categorized from 1 (*not difficult at all*) to 4 (*very difficult*). To assess trialability the perceived availability of the resources necessary to use SODIS over a sustained period of time were recorded. The participants were asked whether they perceive having sufficient sunny surfaces, clear water and transparent PET-bottles at their disposal to prepare as much SODIS-treated water as they need or whether the availability of resources is a barrier to the application of SODIS. The availability of sunny surfaces,
sufficiently clear water and enough transparent PET-bottles was ranged each from 1 (*not available at all*) to 4 (*abundantly available*). The subjective observability of the results of SODIS was measured with the question whether participants had perceived a reduction in diarrhoea episodes when consuming SODIS-treated water. Answers were marked from 1 (*no reduction at all*) to 4 (*very considerable reduction*).

3.2.1.2 Social System

Injunctive norm was operationalized following Ajzen’s (1991) expectancy-value structure. The expectancy what their social network wants them to do is multiplied with the person’s motivation to comply. The perceived expectations of the participants social network were recorded by asking whether and if yes how often participants were told to treat their drinking water. Answers were marked from 1 (*never had been told to do so*) to 5 (*all the time are told to do so*). Motivation to comply was assessed by the participants’ estimation to what degree they would feel motivated to comply with their social network when their social network would apply SODIS and demand participants to do so as well. Answer categories were ranged from 1 (*decision not at all influenced*) to 5 (*decision very much influenced*).

To assess descriptive norm the perception of whether the participants’ social network uses SODIS was recorded. In a first step, participants had to list all the names of the people with whom they have talked in the week preceding the interview. In a second step, it was asked for each of the listed names whether the participants know them to be a SODIS user. Descriptive norm was calculated as the percentage of people known to be SODIS user among the total amount of names listed.
3.2.1.3 Extent of Change Agents’ Promotion Efforts / Communication Channels

This factor was quantified by recording the number of times the interviewed person had received household visits, attended official events and followed mass media transmissions. The number of participated promotion activities for each of these three communication channels then were added up to obtain one measure for the extent of change agents’ diffusion efforts.

3.2.1.4 Percentage of Safe Drinking Water on Total Consumption of Liquids That is not Treated With SODIS

To calculate the percentage of safe drinking water on the total consumption of liquids that is not treated with SODIS the amount of untreated, boiled, SODIS-treated, filtered or chlorinated water as well as the amount of bought bottled drinks consumed throughout an average day was recorded. Except untreated water, all of them were considered as safe drinking water. Thus, the percentage was formed deducting the amount of SODIS-treated water and untreated water from the total amount of liquids consumed in an average day.

3.2.2 Dependent Variables

3.2.2.1 Intention to Use SODIS in the Future

In order to assess the intention to use SODIS in the future, participants were asked how much water that they intended to treat with SODIS in the future. Answers ranged from 1 (no water at all) to 5 (as much water as possible).

3.2.2.2 Percentage of SODIS-Treated Water on the Total Consumption of Liquids

The dependant variable for the current use of SODIS was quantified in terms of the percentage of SODIS-treated water on the total consumption of liquids. The consumption patterns of
liquids consumed throughout an average day were recorded in detail in the first section of the questionnaire. This section provided data on the current SODIS-related behaviour including the percentage of SODIS-treated water on the total consumption of liquids.
4. Results

4.1. General Data on Water Consumption

Sixty percent of the interviewed households stated that they used SODIS, 13% of the households knew about the technology but had not used it yet, whereas 17% had never heard about the technology at all. Ten percent stated that they had used SODIS before but that they have abandoned the use of it.

The amount of water treated with SODIS was on average 33% of the total consumption of liquids. Boiled water consumed at a percentage of 45% averagely was the most widely consumed liquid. Bought drinks were with 3% only a small fraction of the total consumption of liquids. Regarding the consumption of untreated water, 19% of all consumed liquids amounted to be untreated water. Most of the boiled water is consumed in the morning hours when people like to prepare a hot tea, coffee or soup. On the contrary, SODIS-treated water is mainly consumed in the afternoons, when people appreciate to carry a bottle of SODIS-treated water with them, which is easy to transport.

Households which reported to be SODIS users had on average 2.5 bottles positioned outside for SODIS treatment at the time of the interview what amounts to 0.6 bottles per person. Together with the counting of bottles put outside for SODIS treatment, the correct disposition of the bottles was assessed. Nine percent of the bottles and its caps were found to be dirty and 12% not fully transparent. The water used for SODIS was judged to be cloudy in 2% of the bottles, whereas 8% of the bottles were covered by shadow. Moreover, 30% of the households at least partly used bottles larger than 3 litres. These large bottles were widespread because bottled water is usually sold in large units like 5 or 10 litres, however as UV-radiation intensity is reduced by increasing water depth their use is not recommended. Containers used
for SODIS should be as flat as possible, with a water depth of less than 10 cm (Wegelin et al., 1994).

4.2. Descriptive Statistics

Means and standard deviations of the variables derived from the theory of diffusion of innovations are displayed in Table 2. The part of the questionnaire where these variables were recorded was only applicable to participants who have already heard about SODIS ($n = 536$), irrespective whether they have never used it, were actual SODIS user or abandoned the use of it.

The relative advantage of SODIS in terms of cost savings ($M = 2.45$, $SD = .61$), taste of water ($M = 2.69$, $SD = .63$), and enhanced safety of the drinking water ($M = 2.75$, $SD = .57$) reached quite high means on a 3-point Likert scale indicating that all three measured dimensions were indeed valued as advantageous by our sample.

Compatibility with daily tasks and habits reached a mean of 5.73 ($SD = 1.73$) on a 7-point Likert scale indicating that the application of SODIS is perceived as highly compatible with the day-to-day routine of our sample. A mean of 5.39 ($SD = 1.48$) resulted for the perceived vulnerability to contract diarrhoea what reflects that the likelihood of getting diarrhoea is perceived as quite but not very high. Likewise, the severity of diarrhoea with a mean of 3.91 ($SD = 1.28$) on a 5-point scale indicates that the severity of diarrhoea is perceived as quite but not very severe.

Table 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Attributes of the innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Relative Advantage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cost savings (1 = not cost-saving; 3 = very cost-saving)</td>
<td>2.45</td>
<td>.61</td>
</tr>
</tbody>
</table>

Means and Standard Deviations for Independent and Dependent Variables ($n = 536$)
- Taste of water (1 = not tasty; 3 = very tasty) 2.69 .63
- Safety of water (1 = not safe; 3 = very safe) 2.75 .57

2. Compatibility
- Daily tasks and habits 5.73 1.73
  (1 = lowest compatibility; 7 = highest compatibility)
- Threat of diarrhoea
  - Vulnerability (1 = very low; 7 = very high) 5.39 1.48
  - Severity of diarrhoea (1 = not severe at all; 5 = very severe) 3.91 1.28
- Affective beliefs (1 = not enjoyable at all; 7 = very enjoyable) 6.12 1.28
- Cognitive beliefs 3.55 .80
  (1 = no confidence in SODIS; 4 = full confidence in SODIS)

3. Complexity
- Perceived difficulty (1 = not difficult at all; 4 = very difficult) 1.13 .51

4. Trialability
- Sunny surfaces (1 = not available at all; 4 = abundantly available) 3.81 .47
- Clear water (1 = not available at all; 4 = abundantly available) 3.89 .38
- Transparent bottles (1 = not available at all; 4 = abundantly available) 3.25 .89

5. Observability
- Experience of reduction in diarrhoea episodes 3.48 .72
  (1 = no reduction at all; 4 = very considerable reduction)

II. Social System
- Injunctive norm
  - Perceived expectations of social network 3.28 1.03
    (1 = never were told to treat drinking water; 5 = all the time are told to do so)
  - Motivation to comply with social network 2.03 .94
    (1 = very low; 5 = very high)
- Descriptive Norm
  (Percentage of SODIS user in personal communication network) 49 43

III. Extent of Promotion Efforts
- Number of strategies participated .95 .47

IV. Total consumption of safe water
- Percentage of safe drinking water on total consumption of liquids without SODIS 47 30

V. Percentage of SODIS water on total consumption of liquids 39 33

VI. Intention to use SODIS in the future (1 = no water; 5 = as much as possible) 4.63 .77

Affective beliefs reached a mean of 6.12 ($SD = 1.28$) on a 7-point Likert scale indicating that the technology of treating drinking water with SODIS is regarded as enjoyable.

Cognitive beliefs about SODIS reached a mean of 3.55 ($SD = .80$) on a 4-point Likert scale reflecting that people in our sample have high confidence in the technology of SODIS. For the Perceived difficulty resulted a mean of 1.13 ($SD = .51$) on a 4-point Likert scale showing that the correct application of SODIS is perceived as not difficult at all. The availability of enough sunny surfaces ($M = 3.81, SD = .47$) and clear water ($M = 3.89, SD = .38$) did not im-
pose serious constraints on the maximal possible amount of water treatable with SODIS, however the availability of transparent PET-bottles with a mean of 3.25 (SD = .89) on a 4-point Likert scale indicates that they were a more scarce resource. The self-reported perceived reduction in diarrhoea episodes while using SODIS reached a mean of 3.48 (SD = .72) on a 4-point Likert scale indicating that a considerable reduction of diarrhoea was perceived in our sample.

With a mean of 3.28 (SD = 1.03) on a 5-point Likert scale the perceived expectations of the social network scored rather low indicating that people in our sample were not that many times told to purify their drinking water. The motivation to comply with the perceived expectations of the social network scored even lower (M = 2.03, SD = .94) reflecting a low motivation to comply with perceived expectations of the respective social network. Descriptive norm indicated that on average 49% of the personal communication network were known to be SODIS user (SD = .43) what amounts to almost half of the respective communication network.

The mean of the total number of strategies participated was .95 (SD = .47) what means that on average the people in our sample participated in one diffusion strategy. For the segment of the total sample who have already heard about SODIS (n = 536) the mean percentage of SODIS-treated water on the total amount of liquids consumed was 39% (SD = .33). Additionally, participants consumed averagely 47% (SD = .30) otherwise (e.g. boiled water, bought drinks) safe drinking water. The intention to use SODIS in the future reached a mean of 4.63 (SD = .77) on a 5-point Likert scale indicating that on average participants intend to treat a high percentage of their drinking water with SODIS in the future.
4.3. Intercorrelations of Independent Variables

As is typical before presenting multiple regression models, bivariate associations were initially presented. To provide an estimate of the associations among all of the determinants, Table 3 displays the relative intercorrelations.
Table 3
*Intercorrelations for all independent variables (n = 536)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
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</thead>
<tbody>
<tr>
<td>1. Cost savings</td>
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<tr>
<td>2. Taste of water</td>
<td>.46***</td>
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<td>3. Safety of water</td>
<td>.49***</td>
<td>.75***</td>
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<td>4. Daily tasks and habits</td>
<td>.42***</td>
<td>.48***</td>
<td>.46***</td>
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<tr>
<td>5. Threat of diarrhoea</td>
<td>-.15**</td>
<td>.14*</td>
<td>.08</td>
<td>.12*</td>
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<tr>
<td>6. Affective beliefs</td>
<td>.33***</td>
<td>.51***</td>
<td>.47***</td>
<td>.71***</td>
<td>.10</td>
<td>—</td>
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<tr>
<td>7. Cognitive beliefs</td>
<td>.32***</td>
<td>.50***</td>
<td>.46***</td>
<td>.57***</td>
<td>.16**</td>
<td>.66***</td>
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<tr>
<td>8. Perceived difficulty</td>
<td>.09</td>
<td>.00</td>
<td>.00</td>
<td>.06</td>
<td>-.10</td>
<td>.05</td>
<td>.05</td>
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<tr>
<td>9. Sunny surfaces</td>
<td>-.05</td>
<td>-.03</td>
<td>.06</td>
<td>.00</td>
<td>-.07</td>
<td>.07</td>
<td>.04</td>
<td>.04</td>
<td>.13*</td>
<td>—</td>
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<tr>
<td>10. Clear water</td>
<td>-.05</td>
<td>-.03</td>
<td>.06</td>
<td>.00</td>
<td>-.07</td>
<td>.07</td>
<td>.04</td>
<td>.04</td>
<td>.13*</td>
<td>—</td>
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<td></td>
</tr>
<tr>
<td>11. Transparent bottles</td>
<td>.33***</td>
<td>.25***</td>
<td>.24***</td>
<td>.27***</td>
<td>.10</td>
<td>.25***</td>
<td>.29***</td>
<td>-.01</td>
<td>.07</td>
<td>.10</td>
<td>—</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>12. Experience of reduction in diarrhoea</td>
<td>.34***</td>
<td>.34***</td>
<td>.31***</td>
<td>.51***</td>
<td>.09</td>
<td>.58***</td>
<td>.64***</td>
<td>.04</td>
<td>.01</td>
<td>.06</td>
<td>.28***</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Injunctive Norm</td>
<td>.02</td>
<td>.08</td>
<td>.08</td>
<td>.15**</td>
<td>.06</td>
<td>.14**</td>
<td>.22***</td>
<td>-.04</td>
<td>-.07</td>
<td>.07</td>
<td>-.10</td>
<td>.15**</td>
<td>—</td>
<td></td>
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</tr>
<tr>
<td>14. Descriptive Norm</td>
<td>.15**</td>
<td>.29***</td>
<td>.25***</td>
<td>.36***</td>
<td>.17**</td>
<td>.30***</td>
<td>.29***</td>
<td>-.06</td>
<td>-.06</td>
<td>-.10</td>
<td>.01</td>
<td>.28***</td>
<td>.25***</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>15. Number of strategies Participated</td>
<td>.12*</td>
<td>.23***</td>
<td>.16**</td>
<td>.26***</td>
<td>.24***</td>
<td>.14*</td>
<td>.20***</td>
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<td>-.08</td>
<td>.03</td>
<td>.02</td>
<td>.11*</td>
<td>.06</td>
<td>.38***</td>
<td>—</td>
</tr>
<tr>
<td>16. % safe drinking water without SODIS</td>
<td>-.12*</td>
<td>-.19***</td>
<td>-.18**</td>
<td>-.36***</td>
<td>-.01</td>
<td>-.31***</td>
<td>-.12*</td>
<td>.02</td>
<td>-.04</td>
<td>.04</td>
<td>.08</td>
<td>-.11*</td>
<td>-.01</td>
<td>-.34***</td>
<td>-.25***</td>
</tr>
</tbody>
</table>

*Note.*  
* p < .05.  ** p < .01.  *** p < .001. These estimates reflect Pearson product moment correlations.
4.4. Factors Predicting the Percentage of SODIS-Treated Water on Total Consumption of Liquids

A simultaneous multiple regression analysis was performed on the percentage of SODIS-treated water on the total amount of liquids consumed as the dependent variable with the independent variables (IVs) derived from diffusion research.

Table 4 displays the correlations between the IVs and the dependent variable \( (r) \), the unstandardized regression coefficients \( (B) \), the standardized regression coefficients \( (\beta) \) and the variance explained by all predictors adjusted for the number of predictors \( (R^2_{\text{adjusted}}) \). R for regression was significantly different from zero, \( F(16, 519) = 74.54, p < .001 \). Assumptions of normality, linearity and homoscedasticity of residuals as well as independence of errors are deemed to be met.

Out of the 16 IVs, nine contributed significantly to prediction of the percentage of SODIS-treated water on the total amount of consumed liquids. The highest standardized regression coefficient \( (\beta = -0.547, p < .001) \) was reached by the percentage of safe drinking water that is not treated with SODIS on the total consumption of liquids confirming the inverse relationship hypothesized. This result indicates that for each percent clean water people already use except for SODIS, the share of SODIS-treated water drops by about half a percent \( (B = -0.54) \).

A beta weight of 0.165 \( (p < .001) \) resulted for the compatibility with daily tasks and habits confirming the hypothesized relationship. Further variables that contributed significantly to the regression were (a) the descriptive norm, (b) the perceived threat of diarrhoea, (c) the sufficient availability of PET-bottles, (d) the cost-savings, (e) the better taste of SODIS-treated water, (f) the total number of participated strategies as well as (g) the availability of sufficiently clear water all confirming the respective hypothesized relationship.
Table 4  
Correlations and Summary of Simultaneous Multiple Regression Analysis for Variables Predicting the Percentage of SODIS-treated Water on the Total Amount of Consumed Liquids (n = 536)

<table>
<thead>
<tr>
<th>Variables</th>
<th>R</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Attributes of the innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Relative Advantage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cost savings</td>
<td>.322***</td>
<td>.084</td>
<td>.032</td>
<td>.083**</td>
</tr>
<tr>
<td>- Taste of water</td>
<td>.451***</td>
<td>.100</td>
<td>.041</td>
<td>.098*</td>
</tr>
<tr>
<td>- Safety of water</td>
<td>.407***</td>
<td>.039</td>
<td>.040</td>
<td>.038</td>
</tr>
<tr>
<td>2. Compatibility</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>- Daily tasks and habits</td>
<td>.551***</td>
<td>.167</td>
<td>.039</td>
<td>.165***</td>
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<tr>
<td>- Threat of diarrhoea</td>
<td>.255***</td>
<td>.100</td>
<td>.026</td>
<td>.101***</td>
</tr>
<tr>
<td>- Affective beliefs</td>
<td>.470***</td>
<td>-.042</td>
<td>.041</td>
<td>-.042</td>
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<tr>
<td>- Cognitive beliefs</td>
<td>.452***</td>
<td>.035</td>
<td>.040</td>
<td>.035</td>
</tr>
<tr>
<td>3. Complexity</td>
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<td></td>
</tr>
<tr>
<td>- Perceived difficulty</td>
<td>-.055</td>
<td>-.023</td>
<td>.030</td>
<td>-.019</td>
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<tr>
<td>4. Trialability</td>
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<tr>
<td>- Sunny surfaces</td>
<td>.148***</td>
<td>.036</td>
<td>.029</td>
<td>.033</td>
</tr>
<tr>
<td>- Clear water</td>
<td>.072*</td>
<td>.065</td>
<td>.026</td>
<td>.062*</td>
</tr>
<tr>
<td>- Transparent PET-bottles</td>
<td>.235***</td>
<td>.099</td>
<td>.027</td>
<td>.101***</td>
</tr>
<tr>
<td>5. Observability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Experience of reduction in diarrhoea episodes</td>
<td>.248***</td>
<td>-.021</td>
<td>.031</td>
<td>-.020</td>
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<tr>
<td>II. Social System</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>- Injunctive Norm</td>
<td>.155***</td>
<td>.033</td>
<td>.026</td>
<td>.032</td>
</tr>
<tr>
<td>- Descriptive Norm</td>
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<td>.122</td>
<td>.029</td>
<td>.123***</td>
</tr>
<tr>
<td>III. Extent of Promotion Efforts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- No. of strategies participated</td>
<td>.355***</td>
<td>.068</td>
<td>.028</td>
<td>.067*</td>
</tr>
<tr>
<td>IV. Total consumption of safe water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Percentage of safe drinking water without SODIS</td>
<td>-.697***</td>
<td>-.540</td>
<td>.027</td>
<td>-.547***</td>
</tr>
<tr>
<td>Constant (p = .000)</td>
<td></td>
<td>.144</td>
<td>.025</td>
<td></td>
</tr>
</tbody>
</table>

Note. $R^2_{\text{adjusted}} = .69, p < .001.$

$^* p < .05. ^{**} p < .01. ^{***} p < .001.$

Although there were significant correlations between the dependent variable and the (a) better safety of SODIS-treated water, (b) the affective beliefs about SODIS, (c) the cognitive beliefs about SODIS, (d) the availability of sunny surfaces, (e) the perceived experience of reduction in diarrhoea episodes, and (f) the injunctive norm these variables did not contribute significantly to regression. Apparently, the relationship between those six IVs and the dependent variable is mediated by the other IVs in the regression. Perceived difficulty of the technology was the only variable that neither correlated significantly with the dependent vari-
able nor contributed significantly to regression. Altogether 69% of the variability in the percentage of SODIS-treated water on the total amount of liquids was predicted by these 16 IVs.

### 4.5. Factors Predicting the Intention to Use SODIS in the Future

To identify the variables that predict the intention to use SODIS in the future a simultaneous multiple regression analysis was carried out. Table 5 shows the correlations between the independent variables and the dependent variable ($r$), the unstandardized regression coefficients ($B$), the standardized regression coefficients ($\beta$) and the variance explained by all predictors adjusted for the number of predictors ($R^2_{\text{adjusted}}$). R for regression was significantly different from zero, $F (16, 519) = 36.73, p < .001$. Assumptions of normality, linearity and homoscedasticity of residuals as well as independence of errors are deemed to be met.

<table>
<thead>
<tr>
<th>variables</th>
<th>$r$</th>
<th>$B$</th>
<th>S.E. $B$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Attributes of the innovation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Relative Advantage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cost savings</td>
<td>.378***</td>
<td>.082</td>
<td>.040</td>
<td>.081*</td>
</tr>
<tr>
<td>- Taste of water</td>
<td>.468***</td>
<td>.103</td>
<td>.050</td>
<td>.102*</td>
</tr>
<tr>
<td>- Safety of water</td>
<td>.435***</td>
<td>.014</td>
<td>.050</td>
<td>.014</td>
</tr>
<tr>
<td>2. Compatibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Daily tasks and habits</td>
<td>.610***</td>
<td>.179</td>
<td>.048</td>
<td>.177***</td>
</tr>
<tr>
<td>- Threat of diarrhoea</td>
<td>.176***</td>
<td>.016</td>
<td>.033</td>
<td>.016</td>
</tr>
<tr>
<td>- Affective beliefs</td>
<td>.635***</td>
<td>.211</td>
<td>.050</td>
<td>.211***</td>
</tr>
<tr>
<td>- Cognitive beliefs</td>
<td>.605***</td>
<td>.132</td>
<td>.050</td>
<td>.132**</td>
</tr>
<tr>
<td>3. Complexity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Perceived difficulty</td>
<td>-.056</td>
<td>-.060</td>
<td>.037</td>
<td>-.050</td>
</tr>
<tr>
<td>4. Trialability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Sunny surfaces</td>
<td>.252***</td>
<td>.098</td>
<td>.036</td>
<td>.090**</td>
</tr>
<tr>
<td>- Clear water</td>
<td>.041</td>
<td>-.026</td>
<td>.032</td>
<td>-.025</td>
</tr>
<tr>
<td>- Transparent PET-bottles</td>
<td>.332***</td>
<td>.077</td>
<td>.033</td>
<td>.079*</td>
</tr>
<tr>
<td>5. Observability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Experience of reduction in diarrhoea episodes</td>
<td>.400***</td>
<td>.079</td>
<td>.038</td>
<td>.075*</td>
</tr>
<tr>
<td><strong>II. Social System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Injunctive Norm</td>
<td>.230***</td>
<td>.087</td>
<td>.032</td>
<td>.087**</td>
</tr>
<tr>
<td>- Descriptive Norm</td>
<td>.294***</td>
<td>-.040</td>
<td>.036</td>
<td>-.040</td>
</tr>
</tbody>
</table>
Out of the 16 IVs, ten contributed significantly to prediction of the intention to use SODIS in the future. The highest standardized partial regression coefficient ($\beta = 0.211, p < .001$) was reached by the affective beliefs towards SODIS confirming the hypothesized relationship. For the compatibility with daily tasks and habits a beta weight of 0.177 ($p < .001$) resulted and for the cognitive beliefs one of 0.132 ($p < .01$) both confirming the hypothesized relationships.

Further variables that contributed significantly to the regression were (a) the better taste of SODIS, (b) the percentage of safe drinking water except the SODIS-treated water on the total consumption of liquids, (c) the availability of sunny surfaces, (d) the injunctive norm towards SODIS, (e) the cost-saving, (f) the availability of transparent PET-bottles and (g) the perceived reduction in diarrhoea episodes all confirming their respective hypothesized relationship.

Altogether 52 % of the variability in the intention to use SODIS in the future was predicted by these 16 IVs. Although there were significant correlations between the intention to use SODIS in the future and the better safety of SODIS-treated water as well as the perceived threat of diarrhoea both of them did not contribute significantly to regression. The relationship between these two variables might be mediated by the other IVs in the regression. Perceived difficulty of the technology was the only variable that neither correlated significantly with the dependent variable nor contributed significantly to regression.
5. Discussion

5.1. Discussion of Results and Implications for Intervention

The main purpose of this study was to assess the capacity of the variables derived from Rogers’ theory of diffusion of innovations (2003) to predict the use and intention to use of SODIS. The results of the simultaneous multiple regression models predicting use and intention to use of SODIS generally confirmed the hypothesized relationships between dependent and independent variables. More specifically, the multiple regression analysis for the current use of SODIS suggests that (listed in descending order of the height of the respective standardized regression coefficient) (a) the percentage of SODIS-treated water on the total amount of consumed liquids, (b) the compatibility with daily tasks and habits, (c) the descriptive norm, (d) the perceived threat of diarrhoea, (e) the sufficient availability of transparent PET-bottles, (f) the better taste of the SODIS-treated water, (g) cost-savings, (h) the number of promotion strategies participated and (i) the sufficient availability of clear water are significantly influencing the percentage of SODIS-treated water on the total amount of consumed liquids in the hypothesized direction.

The multiple regression analysis for the intention to use SODIS in the future suggests that (listed in descending order of the height of the respective standardized regression coefficient) (a) the compatibility with affective beliefs, (b) the compatibility with daily tasks and habits, (c) the compatibility with cognitive beliefs, (d) the better taste of the SODIS-treated water, (e) the percentage of otherwise treated safe drinking water, (f) the sufficient availability of sunny surfaces, (g) the injunctive norm of the social system, (h) cost-savings, (i) the sufficient availability of transparent PET-bottles, and (j) the experience of reduction in diarrhoea episodes are significantly influencing the intention to use SODIS in the future in the hypothesized direction. By clarifying the most critical theory-based determinants of the use and
intention to use of SODIS, this results may guide the development of more effective diffusion strategies.

With respect to the role of the perceived relative advantage over the method superseded, costs-savings contributed significantly to both the current use and the intention to use SODIS in the future. Likewise, the perceived better taste of the SODIS-treated water significantly predicted both use and intention to use SODIS. Although the correlation between the perceived better safety of the SODIS-treated water and the use of SODIS was .41 \((p < 0.001)\), respectively .44 \((p < 0.001)\) for the intention to use SODIS in the future, the perceived better safety did not contribute significantly to regression neither for the current use of SODIS nor for the intention to use SODIS in the future. It is noteworthy that not the perceived better safety of the drinking water mainly predicted use and intention to use SODIS, but the reduced costs and the perceived better taste of the water. This gives rise to the assumption that the relationship between the perceived better safety and the dependent variables is mediated by other variables in the regression.

To increase the perceived relative advantage of a preventive innovation, any aspect possibly constituting a relative advantage needs to be stressed (Rogers, 2003). With regard to SODIS we anticipated these to be the lower costs compared to boiling water and the sometimes reported better taste of the SODIS-treated water. However, anecdotal evidence from our collection of these data suggests that there are many more possible relative advantages that could be emphasised in future diffusion activities such as less working time and burden for daily activities compared to boiling water, the practicality of transporting, treating and storing water in the same vessel and the handy size of a SODIS-bottle for carrying to the fields. As the perceived relative advantage would change by region and cultural context, initial qualitative discussions with community people, concerning the potential benefit of the technology for their daily life, may identify ways in which a programme should be modified so as to obtain a greater level of adoption.
In particular, complex relative advantages need to be elaborated. With regard to SO-DIS several financial advantages might be meaningful for users, more obvious ones such as the reduction of expenses for traditional energy sources used for boiling water, but also the resulting higher productivity and fewer expenditure for medical care when the user’s health is improved. Considering the fact that the rural and peri-urban areas visited for this study figure among the poorest in the country, according to Soto (2004b) for many of their inhabitants water and sanitation comes a long way down the list of priorities. At the top are things which people believe will have a direct impact on family income and might therefore be seen as more pressing problems to solve, for example improvements to irrigation and agriculture, livestock, transport, and electricity. Hence ‘hygiene’ and even ‘health’ can remain fairly remote and abstract words, ideas that seem to bear little upon the pressing problems of everyday life. It is therefore essential to try to build a clear, practical understanding of the links between hygiene and health, health and productivity, productivity and income.

The perceived compatibility with daily tasks and habits contributed significantly to both the current use of SODIS and the intention to use SODIS in the future. The importance of this predictor is highlighted by the fact that for both dependent variables compatibility with daily tasks and habits resulted as the second largest standardized partial regression coefficient. Therefore, we recommend that careful attention is paid to the full incorporation of SODIS in the daily household routine. Teaching SODIS and delivering bottles is not sufficient, the reorganization of water preparation and consumption needs to be addressed as well. This is a creative process, for example we found evidence that boiled water is often consumed in the morning hours when people like to prepare a hot tea, coffee or soup whereas SODIS-treated water is mainly consumed in the afternoons when people need water during their work in the field or market (Moser, Heri & Mosler, 2005). Therefore, people in some communities started to manufacture and sell shoulder bags designed for SODIS bottles that make their transport even easier.
Further reasons that can seriously hinder the full incorporation of SODIS in the daily household routine are lack of resources or unfavourable climatic conditions (Moser, Heri & Mosler, 2005). For instance, insufficiently clear water or a lack of transparent PET-bottles can hinder people to apply SODIS on a daily basis, however there are solutions like the filtration of the water that is too turbid for SODIS and the set-up of a supply scheme for transparent PET-bottles. Harder to overcome are climatic conditions like the rainy season in the inter-andean valleys that limits the possibility for applying the SODIS technology as a habit throughout the year. Under these climatic conditions, SODIS should be introduced alongside the collection of rain water from a clean area (e.g. from a corrugated or tile roof) and/or an alternative water treatment method. Even though SODIS in itself is a simple water treatment method, changing ingrained habits can prove to be a difficult and long term task. Therefore, a kind of regular follow-up action is indispensable for any SODIS diffusion programme.

Meierhofer (2006) recommends in the EAWAG/SANDEC’s Training Manual for SODIS Promotion that during the first month after the initial training, the SODIS users should be visited once each week, thereafter once each month for the duration of at least one year.

The perceived threat of diarrhoea contributed significantly to the current use of SODIS but not to the intention to use SODIS in the future. One explanation of this difference in line with Rogers’ (1983) protection motivation theory is, that higher threat appraisals combined with a message that contains reassuring behavioural advice will enhance the chance of following the advised behaviour. Therefore, after the process of coping appraisal in which the behavioural options to diminish the threat are evaluated, higher levels of threat appraisal can eventually result in higher percentages of SODIS-treated water on the total consumption of liquids. For the intention to use SODIS in the future, the standardized partial regression coefficient of the threat of diarrhoea is near zero and insignificant. However, as Paz, Soto & Zevallos (2003) stress, the local epidemiological profile does not acknowledge diarrhoeal diseases as health main priorities. Thus, this result might not reflect the unimportance of the
perceived threat of diarrhoea on forming intentions but the unawareness of the actual vulnerability to contract diarrhoea and its severity especially for children under the age of five. Hence, one diffusion strategy is to raise awareness of the ways diarrhoea is transmitted and of the sometimes drastic consequences of diarrhoeal diseases. However, to avoid maladaptive coping reactions such as denial of the threat or avoidance of the fear-evoking message, it is of utmost importance to offer as well advise on what steps can be taken to diminish the likelihood of contracting diarrhoea. Best practice is the introduction of SODIS as part of a more comprehensive water, hygiene and sanitation programme (Soto, 2004a).

The affective beliefs about SODIS resulted as the highest standardized partial regression coefficient significantly predicting the intention to use SODIS in the future which means that the more an individual perceives the application of SODIS is as pleasurable, the more water the individual intends to treat with SODIS in the future. On the contrary, for the current use of SODIS the standardized partial regression coefficient for the affective beliefs is near zero, even indicating a slight inverse relationship, and insignificant. The latter result conflicts with the findings of Altherr, Mosler, Tobias & Butera (in press) who found attitude to be the only common predictor for both use and intention to use of SODIS. Our results suggest that even though promotion activities that focus on developing positive affective beliefs towards SODIS may to a great extent influence the intention to use SODIS in the future, the fostering of positive affective beliefs is not sufficient for the sustained use of SODIS on a daily basis. Positive affective beliefs may be sufficient for giving SODIS a try. However, for the current percentage of SODIS-treated water on the total consumption of liquids, table 5 displays that the positive affective belief is negligible. Therefore, if diffusion activities focus solely on fostering positive affective beliefs and do not build on the various variables that influence the current percentage of SODIS-treated water illustrated in table 5 the SODIS application might not be sustainable.

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Likewise affective beliefs, cognitive beliefs about SODIS significantly predicted the intention to use SODIS which means that the more confidence an individual places in the technology of SODIS, the more water the individual intents to treat with SODIS in the future. However, cognitive beliefs were not influencing significantly the current percentage of SODIS-treated water on the total consumption of liquids.

For the intention to use SODIS in the future, cognitive beliefs resulted as the third largest standardized partial regression weight. The result that cognitive beliefs did not appear to be relevant for actual behaviour may be attributed to the fact, that the end users do not have the mechanism to verify the efficacy of the SODIS-treatment process. We found anecdotal evidence that some local community health workers as well as educated people such as teachers did not directly support SODIS because they did not trust the method. As demonstrations of the effectiveness of SODIS at the field level do reduce skepticism (EAWAG/SANDEC, 2002) and thereby enhance the confidence placed in the technology, we recommend to always accompany initial promotion activities in a new area with the performance and demonstration of microbiological tests. It is important to remember that the purpose of SODIS is not to produce sterile water free of microorganisms, but the inactivation of pathogenic, diarrhoea causing microorganisms. Thus, the total count of bacteria is an inadequate parameter for the assessment of SODIS efficiency, as harmless bacteria might grow during sunlight exposure. In the EAWAG/SANDEC’s Guide for the Application of SODIS, Meierhofer & Wegelin (2002) recommend to use Escherichia coli (E.coli) as indicator organism indicating faecal pollution in the water. Testing for E.coli is also possible under the difficult field conditions in a developing country, for example by using the Oxfam-DelAgua portable water testing kit3.

The hypothesized inverse relationship between Perceived difficulty and the dependent variables was not confirmed in the regression analyses with the standardized partial regression coefficients not being significant for neither the current use nor the intention to use SODIS in

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3 The Oxfam-DelAgua portable water testing kit is available from the Robens Centre for Public and Environmental Health (http://www.rcpeh.com).
the future. However, with regard to our observations of incorrect SODIS-application such as not fully transparent, dirty and heavily scratched bottles, overly turbid water, bottles covered by shadow and recontamination after the treatment process we conclude that even though SODIS is perceived as a simple technology by the target population, the correct application of the technology requires adequate initial training of users.

Trialability in terms of the perceived availability of sunny surfaces necessary to apply SODIS was a significant predictor only for the intention to use SODIS but not for the current use of SODIS. As the mean calculation of the corresponding item displayed in table 2 suggests, sunny surfaces are generally abundantly available and do not present a constraint to the application of SODIS. However, as they significantly influence the intention to use SODIS in the future we suggest that the topic of suitable locations for exposing SODIS bottles to the sun such as roofs, latrines, corrugated iron sheets or any other appropriate place where bottles are fully exposed to the sun and protected from wind cooling should be addressed during promotion activities.

Contrary to the perceived availability of sunny surfaces, the perceived availability of sufficiently clear water resulted to be a significant predictor for the current use but not for the intention to use SODIS in the future. To encourage people who struggle with turbid raw water we recommend that the simple turbidity test using the readability of the SODIS logo’s letters should be demonstrated and if the water is judged too turbid for SODIS, people should be advised on how to filter or decant the solids.

The sufficient availability of transparent PET-bottles is significantly predicting both the current use of SODIS and the intention to use SODIS in the future, though it is more pronounced for the current use of SODIS. The latter result suggests that the availability of PET-bottles may be determining the amount of water that can be treated with SODIS. Thus, the lack of sufficient PET-bottles is a constraint to the widespread use of SODIS, not only, but especially in remote areas. We found that in the majority of our investigation areas, promoters
were supplying bottles to users. While the supply of bottles can help to start using SODIS immediately after the instruction, it creates a dependency and makes it unsure whether people will continue using SODIS after the programme has ended. Furthermore, we found that bottles were distributed only sporadically and in insufficient numbers thus making it more difficult for users to establish a habit of regular SODIS application. We conclude, that in the long run bottles should either be supplied on a regular and sufficient base by an organization that will continue limitless operating in the respective area, or a local scheme for the purchase and transport of used PET-bottles from the city to the villages/peri-urban areas should be initiated. The supply scheme should preferably be combined with a collection scheme of old bottles for correct disposal in order to minimize the amount of waste produced by SODIS.

The observability in terms of the experience of reduction in diarrhoea episodes was predicting significantly the intention to use SODIS in the future but not the current use of SODIS, indicating that other factors than the self-perceived reduction in diarrhoea episodes influence the current use of SODIS. This is not surprising given the fact that even a statistically significant reduction of diarrhoea incidence by 10 to 55% (Hobbins, Indergard & Mäusezahl, 2004) may not be easily observable in everyday life, particularly not under public health conditions like in our investigation areas where diarrhoeal diseases are not acknowledged as health main priorities and where several diarrhoeal incidences per year are regarded as normal (Paz, Soto & Zevallos, 2003). However, intention to use SODIS in the future was significantly predicted by the perceived reduction in diarrhoea episodes, reflecting that people who perceived a decrease in diarrhoea episodes also more likely intend to treat as much water as possible with SODIS.

Regarding the influence of the social system, injunctive norm predicted significantly the intention to use SODIS in the future indicating that the stronger use of SODIS will be approved by the participants social network and as higher the participants’ motivation to comply with these normative beliefs, the more participants intend to use SODIS in the future. Conse-
quently, one means to strengthen the intention to use SODIS in the future is to change the norms of the system with regard to SODIS and other diarrhoea-related preventive innovations through peer support. According to Rogers (2002) changing norms on prevention is a gradual process over time, but can be accomplished, for example by using champions. A champion is an individual who devotes his/her personal influence to encourage adoption of an innovation. Goodman and Stekler (1989) found that champions for health ideas were often middle-level officials in an organization.

Descriptive norm resulted as the third largest standardized partial regression coefficient for the current use of SODIS. Thus, the more people in the participants’ network are known to be SODIS user, the higher is their current use of SODIS. Although the correlation between descriptive norm and the intention to use SODIS was .29 ($p < 0.001$), descriptive norm did not contribute significantly to regression.

These findings suggest that for the everyday use of SODIS the perception whether the participants’ social network actually applies SODIS themselves is much more important than injunctive norms, that is normative beliefs of the social network about SODIS multiplied by the participants’ motivation to comply. This is in line with Rogers’ (2002) findings, that diffusion is essentially a social process in that most individuals evaluate an innovation not on the basis of scientific research by experts, but through the subjective evaluation of near-peers who have already adopted the innovation. The fact that certain innovations are adopted by clusters of individuals (Rogers, 2003) suggest that interpersonal networks among neighbours are powerful influences on individual decisions to adopt. Therefore, we recommend to activate peer networks to diffuse preventive innovations. Anything that can be done to encourage peer communication about a preventive idea, such as for example exposing SODIS bottles on highly frequented places and offering workshops for community based organizations, thus encourages adoption.
The number of promotion strategies actively participated in predicted significantly the current use of SODIS indicating that the more strategies people have participated in, the higher is their percentage of SODIS-treated water on the total consumption of liquids. Although the correlation between the number of strategies participated and the intention to use SODIS in the future was .20 \((p < 0.001)\), the number of strategies participated did not contribute significantly to regression.

These results suggest employing as many different promotion strategies as possible to take advantage of their respective strengths. Mass media channels for example are more effective in creating initial knowledge of innovation, whereas interpersonal channels are more effective in forming and changing attitudes toward a new idea, and thus in influencing the decision to adopt or reject it (Rogers, 2002). There was clearly not made full use of the advantages of mass-media in our investigation areas. Singhal & Rogers (1999) explicitly recommend to use entertainment-education to promote preventive innovations. Entertainment-education is the process of placing educational ideas, such as on prevention, in entertainment messages in order to achieve behaviour changes. For an entertainment-education campaign to be successful, it is best planned on the basis of formative research with the intended audience, its messages should be pre-tested and be lively as well as relevant (Rogers, 2003).

In comparison to the underused communication channel of the mass media, household visits were frequently done. However, as further elaboration of the data (Moser, Heri & Mosler, 2005) indicates, there are considerable differences on how SODIS promoters’ household visits were perceived by the households and thus facilitated the process of incorporating SODIS in household life. As SODIS promoters’ ability to address families’ potential initial reluctance and doubts as well as specific technical and social problems is decisive for the effectiveness of household visits, there is potential for improvement. Consequently, emphasis should be placed on the careful selection, training and supervision of SODIS promoters as
described in the EAWAG/SANDEC’s *Training Manual for SODIS Promotion* (Meierhofer, 2006).

The hypothesized inverse relationship between the percentage of safe drinking water on the total consumption of liquids consumed without the one treated with SODIS and the dependent variables was confirmed in the regression analyses. The percentage of safe drinking water without the one treated with SODIS was significantly predicting both the current use of SODIS and the intention to use SODIS in the future, though it is more pronounced for the current use of SODIS. The percentage of safe drinking water without the one treated with SODIS was by far the largest standardized partial regression coefficient predicting the current use of SODIS indicating that the more otherwise safe drinking water is consumed the lower is the percentage of SODIS-treated water on the total consumption. Considering that the aim of the SODIS implementation was to accumulate a large number of SODIS users without rejecting already existing water disinfection habits, these results do confirm adherence to the implementation message.

Another interpretation would be that people are less likely to adopt SODIS when another technique is already in use. For household that already boil part of their drinking water, we therefore recommend to implement SODIS as a complimentary water treatment method making the goal of 100% clean drinking water possible.

### 5.2. Limitations of the Study

A caveat of the results reported is that because of the cross-sectional nature of the data, it was imperative that our developed and tested multiple regression models were guided by theory. Thus, the directions of effects described in this study are based solely on theory and the efficacy of our entire set of predictors could be tested better with prospective data. The cross-sectional design of our study does not take into consideration the process dimension of the
innovation-decision process as described by Rogers (2003). However, the innovation-decision process provides a theoretical basis for designing programmes with interventions timed and targeted to the various stages of the diffusion process, the types of people expected to be adopting at each stage, and the sources of influence to which they are expected to respond. Future research might operationalize and test the whole innovation-decision process in a longitudinal design in order to provide empirical findings to the scarcity of research on the innovation-decision process.

Further methodological caveats are that the selection of the sample was not representative, that the data was collected by an interviewer team and that it was self-reported. Regarding the results of this study, it has to be considered that even tough a lot of variables turn out to be significant predictors of the use and intention to use of SODIS, the corresponding effects are rather small, except for the percentage of safe drinking water consumed without the one treated with SODIS. More research should be conducted in the quest for other maybe more relevant predictors of the SODIS-related behaviour.

5.3. Conclusions

To sum up, the above discussion demonstrates that a broad array of diffusion theory-based determinants significantly influences the use and intention to use of SODIS. Analyses of these variables indicate several suggestions for tailoring future SODIS diffusion strategies. The data was collected in a large and varied sample of Bolivia justifying some generalization of the results found, however when designing diffusion activities our recommendations always need to be adapted having the respective target population and local conditions in mind. With regard to the worldwide diffusion of SODIS, it is important to remember that preventive innovations generally diffuse relatively slowly even when promising diffusion strategies are utilized (Rogers, 2002). Nevertheless, the diffusion of viable innovations from those who
have them to those who need them is key in worldwide health promotion efforts and without successful diffusion strategies facilitating widespread diffusion of health-related innovations they will realise only a fraction of their potential in preventing avoidable disease and premature death.

Even though meeting the Millennium Development Goals target of halving the proportion of people without sustainable access to safe drinking water and basic sanitation were a crucial step forward, millions of children will continue to die every year up until 2015 and thereafter from preventable water-borne diseases. SODIS is a low-cost and simple point-of-use water treatment method that can be adopted immediately in advance of centralized water treatment and distribution systems, thus accelerating health gains and paving the way for universal access to safe drinking water.
6. References


7. Annex

- Questionnaire