Determinants of the diffusion of SODIS

A quantitative field study in Bolivia

Summary report

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Executive Summary

Solar water disinfection (SODIS) represents a simple, low cost technology for the treatment of drinking water on a household-level. Safe drinking water is provided by exposing water-filled plastic bottles to sunlight allowing the combined germicidal effects of both UV radiation and heat to kill waterborne pathogens.

Despite the obvious advantages of the technology and considerable promotion activities, in some areas SODIS has encountered a rather slow and limited uptake. In order to gain insight into this discrepancy a field survey was conducted using a questionnaire based on a set of theories from social psychology as well as diffusion theory. Two main research questions were focused upon: Firstly, we wanted to gain insights into which were the most important factors that influence the adoption or rejection of SODIS. Secondly, we wanted to examine which diffusion strategy or combination of strategies fosters the diffusion of SODIS the best.

The field work included visits to 8 different areas in Bolivia, selected from criteria such as different geographical location (valley, highlands, lowland) and different levels of urbanisation (suburban, rural), the presence of different NGOs as well as the duration of the project already carried out. In total, 644 households were interviewed, 80 in Alto Sebastian Pagador, a suburb of Cochabamba, 80 in rural communities near Tiraque, 80 in each of two districts of Potosí, 76 in rural communities near Llallagua/Uncía, 81 in communities of Caripuyo near Oruro and 80 in communities near Villa Tunari, and 87 in Yapacaní.

The study found that many households already boil their water, the total amount of households that boil their water differs considerably between the zones. Nevertheless, the majority drinks a couple of glasses of untreated water in the afternoon when the boiled water which was prepared in the morning has been finished. The implementation of SODIS in areas where boiling water is popular should not aim to replace the boiled water, but to supplement it. Therefore, one of our recommendations is to analyse the water consumption behaviour before selecting a new area and to support the people in reorganizing their water preparation and consumption patterns. To promote SODIS as an afternoon beverage can be especially beneficial to the health of people in areas where

water is usually boiled in the morning to prepare a hot beverage but drunk untreated in the afternoons.

The examination of the factors influencing the use of SODIS revealed that habits exert the strongest influence on the percentage of SODIS-treated water on the total consumption of liquids as well as in the intention to use SODIS. Altering existing habits and the development of new habits is a rather difficult process and normally takes several months or even years. Thus, a further recommendation is to accompany people regularly over a long period of time to reduce possible factors which could disturb the process of the development of a new habit. The most cited reasons in our survey for not using SODIS or having stopped using it were the lack of time (24%), cold or rainy weather periods (14%) and lack of sufficient bottles (13%). Therefore, it seems necessary to focus on the factor of the availability of sufficient bottles as the lack of time can be overcome by the smooth integration of SODIS into the daily task routines and to change the weather is out of our control. Our recommendation was to place emphasis on a regular and sufficient supply of bottles, through the local organisations and, whenever possible, through self-organisation of the household, neighbourhood or community.

A last recommendation is to foster intensively the social exchange about SODIS in the communities. Our results indicate that the more people a person has seen using SODIS the higher the percentage of SODIS-treated water is of the total consumption of liquids. This insight should be used in exposing SODIS bottles on highly frequented and well visible places, e.g. schools, health centres, community houses, but also on the houses of mayors, teachers, promoters, and so on. Furthermore, the communication should be stimulated in a way that people know who else in the community uses SODIS.

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1. Introduction

The World Health Organisation estimates that currently 1.1 billion people do not have access to safe drinking water. For many others, the contamination of water during transport and in the household presents a significant risk. 2.2 million die every year of basic hygiene related diseases such as diarrhoea. The great majority are children under five years in developing countries.

Because of its simplicity, low cost, and the need only for plastic bottles and sunlight, the SODIS system developed by scientists at the Swiss Federal Institute for Environmental Science and Technology (EAWAG) and its many collaborators and partners, is an important contribution to the treatment of water at household-level. Safe drinking water is provided by exposing water-filled plastic bottles to sunlight, allowing the combined germicidal effects of both UV radiation and heat to kill waterborne pathogens. Given the abundance of sunlight, the large availability of PET-bottles for a minimum investment, the straightforwardness of the technology and the possible health risks resulting from diseases caused by waterborne pathogens, it is not evident why SODIS has encountered a rather slow and limited uptake in some areas.

Therefore, the present research focused upon two main research questions. Firstly, we wanted to gain insights into which were the most important factors that influence the use or non-use of SODIS. Secondly, we wanted to examine which diffusion strategy or combination of strategies fosters the diffusion of SODIS the best.

Our questionnaire was developed from a pilot study in Nicaragua and is based on a set of theories from social psychology as well as from diffusion theory. In chapter 2, an overall description the methodology of the investigation is provided, including a description of the questionnaire, a characterisation of the sample as well as comments about the statistical methods used. Chapter 3 contains descriptive data about the adoption rate of SODIS and the general patterns of water consumption in the different investigation areas. Chapter 4 deals with the factors affecting the use of SODIS whereas in chapter 5, influences of SODIS on health are examined. In Chapter 6, the different diffusion strategies are evaluated and in chapter 7, some recommendations which emerged from our research are presented for discussion.

2. Realisation of the investigation

2.1. General procedure

The implementation of the present study took place in July and August 2004 in different areas of Bolivia. To reach the best representativity possible as well as some variance in our data, we chose these investigation areas on the basis of different criteria. Besides the accessibility and the common language (we only had Spanish and Quechua speaking interviewers at our disposal) we selected geographically different located areas (valley, highlands, lowland) and different levels of urbanisation (suburban, rural). Further criteria were the field of activity of the different local NGOs and the duration of presence in the field of the implementing agencies (NGOs, government entities). A detailed overview of the characteristics of our investigation areas is shown below in table 1.

Table 1: Selection criteria by investigation area

Name of the investigation area	Alto Sebastian Pagador	Tiraque	Yapacaní	Potosí (San Pedro)	Potosí (San Gerardo)	Uncía / Llallagua	Caripuyo	Villa Tunari
Department	Cbba	Cbba	Santa Cruz	Potosí	Potosí	Potosí	Cbba	Cbba
Communities visited		Chaqo Tora Lapa Baja Pista 15 de octubre Parra Rancho	Patujusal Challavito Los Yukis La Ele Santa Fe			Jachasi Juyo Lawa Lawa	Chiwirapi Janco Janco Jacojo	Villa Fatima Tocopilla
Geographic location	Valley	Valley	lowland	Highlands	Highlands	Highlands	Highlands	lowland
Urbanisation	Suburban	Rural	Rural	Suburban	Urban	Rural	Rural	Rural
Local promotion organization	Fundación SODIS	PCI Cochabamba	CEPAC	CENPOSEP	Spontaneous diffusion	UNICEF UTIM	PCI Oruro	EXTENSA
Beginning of promotion strategies	2003	2000	2003	1999	No promotion strategy was actively promoted	2003	2001	2004
Number of households interviewed	80	80	87	80	80	76	81	80

There was a variety of different strategies carried out as we will examine further in the sixth chapter, where the various diffusion strategies are going to be evaluated. The projects of the NGOs differ in great extent regarding 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 is 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 in Potosí, no active diffusion strategy at all took place.

However, the inhabitants of San Gerardo benefited from the broadcasts on radio and television explaining the use of SODIS which were produced through the NGO working in the neighbourhood of San Pedro in their common city of Potosí.

Finally, 644 families in 8 different investigation areas had been interviewed: 80 in Alto Sebastian Pagador (a suburb of Cochabamba), 80 in rural communities near Tiraque, 87 in rural communities near Yapacaní in the department of Santa Cruz, 80 in each of two districts of Potosí, 76 in rural communities near Llallagua/Uncía (department of Potosí), 80 in communities of Caripuyo near Oruro and 80 in communities near Villa Tunari (both in the department of Cochabamba). The geographical locations of these areas are marked in Figure 1. As illustrated with different colours in Figure 1 the map of Bolivia can be divided into approximately three different geographical areas: The south western part comprises the Andean region, the highland. In the north eastern part lies the lowland with tropical climate and between these two there is a fertile valley of medium altitude.

Figure 1: Map of the investigation areas

The interviews were carried out by a Bolivian interviewer team, under the coaching and supervision of the authors of the present study in cooperation with a Bolivian master student and staff of the SODIS foundation. One of the selection criteria for the interviewer was mother tongue or fluency in Quechua.

In each investigation area the whole team was stationed for 3 to 5 successive days, on which the interviews were carried out. The interview sessions had been prepared by written and oral coordination with local partner organisations and local authorities in order to announce our visit. In this action lies the potential risk of manipulation of the interviewed households in a desired direction by the local organisation or local authorities. But without this previous cooperation it would not have been possible to gain the confidence and willingness to participate of the people, who live mostly isolated and reserved in mainly traditional Quechua communities, besides the fact, that it would not have been possible to find these communities without local guidance.

In the small rural communities we tried to interview all inhabitants as far as possible. That meant that all families who were present during the days of our visit in the area and who were willing to participate were interviewed. The willingness to participate in rural areas was surprisingly high. Thanks to the good preparation by the partner organisations, people had lost their mistrust and felt pleased that somebody was showing interest for their situation. In cases where a family was not present on the first visit, the interviewer tried again in the evening or early the following morning. Thus, only a few families were not reached. In the suburban areas a total investigation was not possible. Therefore, we drew a random sample by distributing the interviewers equally over the blocks, advising them to interview only every third household (or every fifth household, depending on the number of inhabitants of the area).

One interview took around 45 minutes. To show our gratitude for participation, each family received a small gift pack consisting of cooking oil, rice and soap. Then, the collected data was entered into a computer data file (SPSS) by a team of the statistic department (Centro Estatistico Aplicada, CESA) of the San Simon University in Cochabamba.

2.2. Questionnaire

Data collection was based on a structured interview, which was composed of a demographic part, questions and observational items about water consumption and use of SODIS, questions about individual factors influencing the use of SODIS, social factors influencing the use of SODIS (network analysis) and questions about attended promotion strategies.

The questions were developed on the basis of diffusion theories (Rogers, 2003) and theories of social psychology (see Chaiken, Wood & Eagly, 1996; Petty & Cacioppo, 1986). Some of the questions had already been used in a pilot study in Nicaragua (Altherr, Mosler & Tobias, 2004; Altherr, Mosler, Tobias & Butera, submitted), some were developed on experiences of the Swiss Tropical Institute (Hobbins, 2004) or were taken over from a monitoring questionnaire of the SODIS Foundation and slightly revised.

To exclude cultural and linguistic misunderstandings the questionnaire was revised by staff of the SODIS Foundation and the interviewer team, who also jointly translated the instrument into Quechua (orally). The applicability of the questionnaire was tested with a pretest in Lagunitas, a rural community approximately a two-hour bus ride away from Cochabamba in the geographical area of the valley.

With exception of a few open questions, the questionnaire contained given answer categories. These were either different categorical groups or 4-, 5- or 7-point Likert scales, as presented in an example below in figure 2. The complete questionnaire is enclosed in the annex.

To what degree is your health affected when you suffer from diarrhoea?
q   (5) Very severely affected
q   (4) Severely affectecd
q   (3) Not that severely affected
q   (2) Not severely affected
q   (1) Not at all severely affected

Figure 2: Example of a Likert scale item

The interviewer had to ask the questions openly and mark the answer category that fitted the given response best. In case an unambiguous choice of the answer category was not

possible, the interviewer had to clarify and ask again to get a more definite answer. At the end of the interview, the interviewed person had the possibility to add open comments about the conduction and content of the interview and the topic of water and SODIS in general.

2.3. Characterisation of the sample

As already mentioned, the interviews were conducted in Spanish (53%) or Quechua (47%). The average age of the adult persons living in the interviewed households is 36 years. The average years of education are 5.3, but there is quite a higher average in the suburban areas than in the rural ones. A detailed overview on the characteristics of each investigation area can be found in table 2.

A direct question about salary or property was not possible due to the Bolivian culture. Therefore the property was estimated on statements concerning animal and vehicle property and the observation of the living conditions. Based on this information the interviewed families were divided into 7 categories according to their property, ranging from 0 - 2000$ to 12 000 – 14 000$. The average of the property lies in the category of 2000 – 4000$. Tiraque and Potosí seem to be slightly wealthier regions with an average of property between 4000 and 6000$. Employment differs between the areas. In the suburban areas, the interviewed mostly work in the informal sector (Pagador), in formal employment (Potosí) or have other occupations, which mostly contains people in education or without any occupation. In the rural areas, the major part of the persons interviewed work in agriculture.

Table 2: Overview of the demographic characteristics of the investigation areas

	Alto Sebastian Pagador	Tiraque	Yapacaní	Potosí (San Pedro)	Potosí (San Gerardo)	Uncía / Llallagua	Caripuyo	Villa Tunari	Overall total
Language of the interview	Spanish: 87% Quechua: 13%	Spanish: 29% Quechua: 71%	Spanish: 74% Quechua: 26%	Spanish: 86% Quechua: 14%	Spanish: 83% Quechua: 17%	Spanish: 4% Quechua: 96%	Spanish: 19% Quechua: 81%	Spanish: 41% Quechua: 59%	Spanish: 53% Quechua: 47%
Mean age of family members older than 16 years	32.1	33.9	34.0	36.7	34.2	39.6	41.4	35.5	35.9
Mean years of Education	6.4	5.1	4.6	7.6	7.7	2.7	4.3	3.8	5.3
Property	2000-4000$	4000-6000$	2000-4000$	4000-6000$	4000-6000$	2000-4000$	2000-4000$	2000-4000$	2000-4000$
Employment	Informal work (39%)	Agriculture (51%)	Agriculture (81%)	Formal employment (27%) Other (38%)	Formal employment (25%) Other (42%)	Agriculture (57%)	Agriculture (70%)	Agriculture (78%)	Agriculture (37%) Informal work (15%) Formal employment (14%) Other (25%)
Mean number of persons per family	5.4	5.8	5.3	6.1	5.1	4.4	6.9	4.5	5.1
Mean number of children under 5 years	1.1	1.1	1.0	0.74	0.8	0.9	0.8	1.0	0.9
Sex of the person responsible for water	80% female 20% male	86% female 14% male	72% female 28% male	91% female 9% male	80% female 20% male	91% female 9% male	74% female 26% male	68% female 32% male	80% female 20% male
Water source	Water tank trucks (99%)	Water supply network (96%)	Wells (97%)	Water supply network (99%)	Water supply network (100%)	Water supply network (96%)	Water supply network (96%)	Wells (66%) Rivers/streams (29%)	Water supply networks (60%) Wells (22%) Water trucks (12%) Rivers/streams(4%)
Water storage	Barrels (95%)	Buckets (80%)	Buckets (99%)	Buckets (80%)	Buckets (79%)	Buckets (86%)	Buckets (93%)	Buckets (100%)	Buckets (77%) Barrels (14%)

The average family size is 5 persons and on average there is 1 child under the age of 5 years in each family. In 80% of the interviewed households the person of the family responsible for the drinking water is female.

Water source and water storage vary in different areas. In Pagador the water is delivered by water tank trucks. In the tropical areas, the water sources are wells (Yapacaní, Villa Tunari), rivers and streams (Villa Tunari). All other investigated areas have water distribution networks, normally with one tap in the court yard. In Pagador, people store their water in barrels whereas in all other areas drinking water is stored in buckets.

2.4. Statistical analysis

We conducted data analysis with the statistical program SPSS (Version 11). The results are presented in the following result chapters.

To describe our results we normally present frequencies in **percent** or means with further indication of the standard deviations. A **mean** (symbolized by **M**) is the sum of the scores divided by the number of scores. The **number of cases** used for a certain calculation is symbolized by (**N**), the **level of significance** by (**p**). We used the common level of significance of $p < 0.05$ for hypothesis tests (Hypothesis 0 versus Hypothesis 1). Thus, the probability of wrongly rejecting the null hypothesis if it is in fact true is 5%. If for example a comparison of means reaches this significance level, it signifies that with 95% probability the means are different (H_1) and with 5% probability the means do not differ (H_0). Some results reach a significance level of $p < 0.01$ or even $p < 0.001$, which means that the probability of wrongly rejecting the null hypothesis in the former case is 1% and in the latter 0.1% only. Values which reach a significance level of $p < 0.05$ are marked with (*), values with a significance level of $p < 0.01$ with (**) and values with a significance level of $p < 0.001$ with (***).

To analyse relationships between two phenomena, **correlations** were calculated. They measure how strongly two variables are related, or change, with each other. Two variables are positively correlated when they tend to move up or down together. If they tend to move in opposite directions, then they are negatively correlated. The critical measure is the determination coefficient (r^2), which provides an index of the paired variance, caused by a

linear relationship between the two measures. The determination coefficient lies between –1 and +1. A coefficient of 0 means that no relation exists between the two phenomena, +1 means that a perfect positive, -1 that a perfect negative relationship between the phenomena exists. For studies in social sciences, a coefficient of 0.10 can be interpreted as a weak relationship, a coefficient of 0.30 as a reasonable and a coefficient of 0.50 or higher as a strong relationship between the two variables.

Furthermore, we conducted ***multiple regression analyses***. With this calculation, the relationship between one dependent variable and several independent variables (called predictors) can be analysed. Two measures are of interest. The ***multiple regression correlation coefficient*** (R^2) shows how much of the variance of the dependent variable can be explained. The bigger R^2 is, the more of the variance is explained. If R^2 is 1, all of the variance of the dependent variable can be explained by the used independent variables. This would be an actually unlikely result, because in social scientific studies further possible influences always exist and it is impossible to measure all of them. Because the sample size can influence the meaning of the R^2, we used the adjusted multiple regression correlation coefficient ($R^2_{adjusted}$) which is corrected by the sample size.

The second measures of interest are the ***Beta weights*** (β), which are the standardized regression coefficients. They describe the relationship between the dependent variable and each predictor and can be interpreted as the average amount by which the dependent variable increases when the independent variable increases by one standard deviation and other independent variables are held constant. The ratio of the beta weights is the ratio of the predictive importance of the corresponding independent variable.
That means when an independent variable with the Beta weight .35 is increased by one standard deviation, the dependent variable will increase by .35. Thus, the ratio of the beta weights can give important information, about which one of the independent variable is worthwhile to work on for increasing it.

3. Diffusion of SODIS in the investigation areas

3.1. Adoption rate

When comparing the different adoption rates it is important to bear in mind that the projects were in fact very different. As was illustrated in table 1 of the 2nd chapter they started between 1999 and 2004, and for example in the neighbourhood of San Gerardo in Potosí no active promotion strategies were undertaken; whereas the project in Villa Tunari started only a couple of months before our investigation took place, and the main focus is not the promotion of SODIS but medical aid in general. Moreover, the promotion activities carried out by the NGOs were rather different in approach and scope as will be examined further in chapter 6 under the evaluation of the different diffusion strategies.

Table 3: Adoption rate in the different investigation areas

	Never heard of SODIS	Know about SODIS, but have never used it	Current SODIS user	Used SODIS before, but abandoned the use of it	Availability of SODIS water during the interview
Alto Sebastian Pagador	15%	17.5%	48.8%	18.7%	6.3%
Tiraque	0%	12.5%	71.3%	16.2%	35.5%
Yapacaní	5.7%	19.5%	64.4%	10.4%	42%
Potosí (San Pedro)	2.5%	6.3%	80%	11.2%	55%
Potosí (San Gerardo)	33.8%	20%	36.2%	10%	20.3%
Uncía	2.6%	2.6%	92%	2.6%	72%
Caripuyo	0%	2.5%	88.8%	8.7%	50%
Villa Tunari	73.7%	18.8%	2.5%	5.0%	0%

As illustrated in Table 3, about 60% of the interviewed households stated that they used SODIS. 13% of the households knew about the technology but had not used it, whereas 17% had never heard about the technology at all. 10.4% stated that they had used SODIS before but abandoned the use of it.

Table 3 shows that there is a marked difference between the adoption rate of SODIS in the eight different investigation areas, ranging from 2.5% self-reported SODIS users in Villa Tunari to 92% in Uncía. Even though no active promotion strategies were undertaken in the neighbourhood of San Gerardo in Potosí, a considerable number of 36.3% SODIS users were found. This is due to fact that the NGO working in the neighbourhood of San Pedro in Potosí had financed a number of radio and television campaigns promoting

SODIS, which were broadcasted throughout the whole city of Potosí. Additionally, spontaneous diffusion may have occurred.

The rather high rates of SODIS users need to be assessed by looking at the percentage of households that were able to offer SODIS treated drinking water at the time of the interview. The last column in Table 3 shows that on average 35% of the households had SODIS water available ranging from 0% in Villa Tunari to 72% in Uncía. The considerable differences between the self-reported SODIS use and the actual disposition of SODIS-treated water at the time of the interview gave rise to different assumptions. Of course it is possible that the weather or the lack of bottles did not permit applying SODIS on the day of the interview and/or on the day preceding the interview although they usually apply SODIS whenever possible. Still, it has to be considered that the discrepancy between the self-reported SODIS use and the actual disposition of SODIS-treated water may be attributed to a positive answer tendency in order to please the interviewer and the promoter from the local organisations with whom we cooperated.

The self-reported current SODIS users were asked further about how often in the last week they applied SODIS and for how many days they consumed SODIS-treated water.

Table 4: Number of days SODIS was applied and consumed within the last week (question only answered by self-reported SODIS users)

	Frequency of application in the last week				Frequency of consumption in the last week		
	Never	1-3 days	4-7 days		Never	1-3 days	4-7 days
Alto Sebastian Pagador	7.9%	76.3%	15.8%		7.9%	42.1%	50%
Tiraque	5.3%	49.1%	45.6%		5.4%	32.1%	62.5%
Yapacaní	1.8%	32.7%	65.5%		1.8%	27.3%	70.9%
Potosí San Pedro	0%	18.8%	81.2%		1.6%	6.2%	92.2%
Potosí San Gerardo	0%	41.4%	58.6%		0%	17.2%	82.8%
Uncía	1.4%	20%	78.6%		1.4%	5.7%	92.8%
Caripuyo	1.4%	19.7%	78.9%		1.4%	9.9%	88.7%
Villa Tunari	50%	50%	0%		50%	0%	50%

Table 4 shows that there are considerable differences between the different investigation areas in the frequency of application and consumption of SODIS water. Regarding the shortage of bottles it is considered that most households should apply SODIS at least four times a week in order to provide sufficient SODIS-treated water for the household to drink

SODIS-treated water only. The percentage of households which applied SODIS 4 days or more in the week before the interview varies from 0% in Villa Tunari to 81.2% in the neighbourhood of San Pedro in Potosí. However, the frequency of consumption of SODIS-treated water in the week before the interview was reported to be 4 days or more in 50% of the households which use SODIS in Alto Sebastian Pagador and Villa Tunari to 92.8% in Uncía.

The households which stated that they neither applied nor drank SODIS-treated water in the week before the interview but nevertheless reported themselves as SODIS users mentioned reasons such as lack of bottles, lack of time or cold weather making it uncomfortable to prepare SODIS for households without taps that alleviate the filling of the bottles in cold weather conditions.

In the households which reported to be SODIS users, the number of bottles that were actually found positioned outside for SODIS treatment at the time of the interview had been counted. The average number of bottles positioned outside at the time of the interview is illustrated in Figure 3.
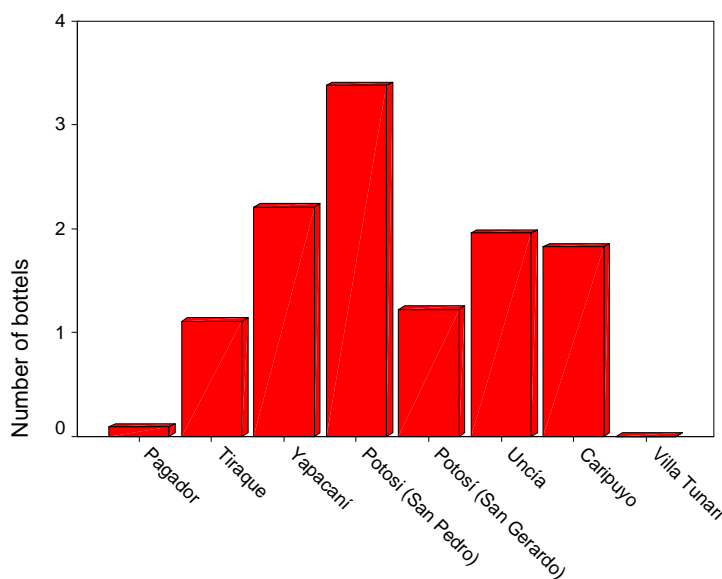

Figure 3: Number of bottles put outside for SODIS on the moment of the interview
        (per household / only counted in households that reported to be SODIS-user)

The average number of bottles put outside ranged from 0 bottles in Villa Tunari to 3.38 in the neighbourhood of San Pedro in Potosí.

Together with the counting of bottles put outside for SODIS treatment, the correct disposition of the bottles was assessed. Generally, the bottles were correctly disposed. 9% 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 at least partly were covered by shadow. Moreover, 30% of the households at least partly used bottles larger than 3 litres. These large bottles are widespread because bottled water is usually sold in large units like 5 or 10 litres, but the use of vessels containing more than 3 litres is not recommended as the combined disinfecting process of heat and UV-radiation may not work properly.

3.2. Consumption patterns of liquids in the investigation areas

Furthermore, the pattern of consumption of any liquids was recorded in order to recognize whether the family boils their water or whether they drink untreated water. It turned out that some years ago a cholera epidemic occurred in Bolivia which led to a large number of families boiling their water instead of drinking it untreated. Table 5 shows that boiled water consumed at a percentage of 45.4% is the most consumed liquid. Closely following with 32.7% of all consumed liquids SODIS-treated water is to be found. Bought drinks are popular too, with 3% of all consumed liquids. Regarding the consumption of untreated water, 18.9% of all consumed liquids is still untreated water. There are considerable variations in the different investigation areas, ranging from 6.3% of untreated water in the neighbourhood of San Pedro in Potosí to 61.7% in Villa Tunari.

Table 5: Average percentage of consumption of untreated, boiled, SODIS-treated water and bought drinks on total consumption of liquids as well as percentage of safe drinking water on total consumption of liquids

	% of untreated water on total consumption	% of boiled water on total consumption	% of SODIS-treated water on total consumption	% of bought drinks on total consumption	% of safe drinking water on total consumption
Alto Sebastian Pagador	8.9	65.1	15.2	10.3	91.1
Tiraque	8.9	56.8	31.7	2.6	91.1
Yapacaní	25.8	38.6	34.5	1.1	74.2
Potosí (San Pedro)	6.3	42.4	46	4.7	93.7
Potosí (San Gerardo)	19.1	60.2	18.6	2.1	80.9
Uncía	11.5	30.7	56.9	.9	88.5
Caripuyo	8.2	34.5	56.6	.7	91.8
Villa Tunari	61.7	35.1	1.5	1.7	38.3

Only one family in Alto Sebastian Pagador reported to use chlorine to treat their water; people stated that the chlorine-treated water would taste like soap and that therefore no one would use it. The use of filters for the treatment of drinking was not popular in the areas of Bolivia we visited. Apart from the fact that the technology of filtering water is rarely or not known in remote areas, the purchase of a proper filter would not be financially feasible for a majority of families.

The percentage of SODIS-treated water on the total consumption of liquids ranges from 1.5% in Villa Tunari to a 56.9% in Uncía. The average over all eight investigation areas shows that roughly one third of the total amount of consumed liquids is SODIS-treated water.

The last column of Table 5 reveals the percentage of safe water (boiled and SODIS-treated water as well as bought drinks) on the total consumption of liquids. The amount of safe drinking water on the total amount of consumed liquids turned out to be as high as 81.1% over all investigation areas. The lowest percentage of safe drinking water was recorded in the tropical areas of Villa Tunari with a percentage of 38.3 and Yapacaní with 74.2%. Given the additional diseases brought on by a tropical climate the rather low percentage of safe drinking water consumed could indicate that diffusion activities in order to promote SODIS would be especially beneficial for the huge population living in the tropical areas of Bolivia.

3.3. Consumption of water during the course of the day
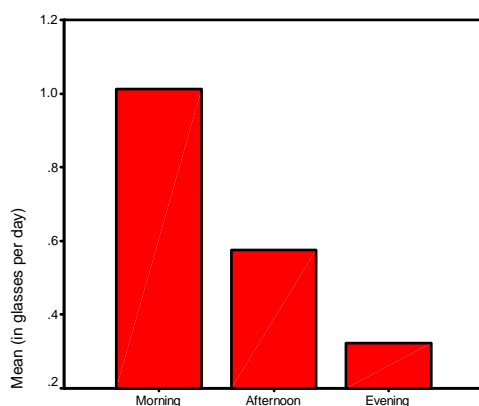

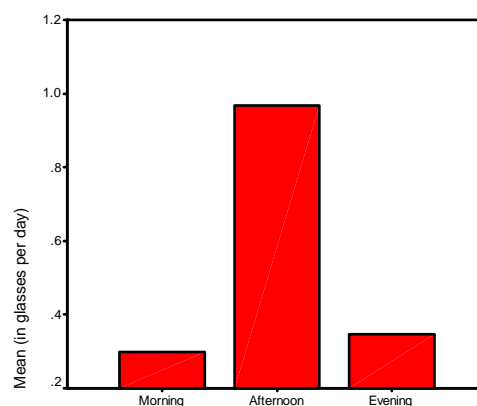Figure 4: Consumption of boiled water / Per Person

Figure 5: Consumption of SODIS water/ Per Person

Figure 4 illustrates that 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, Figure 5 shows that 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. Consequently, boiling water and preparing SODIS-treated water do not necessarily exclude themselves, the daily life patterns of the people make the methods fit very well together. For a lot of families it is not feasible to boil water twice a day, hence they consume untreated water for the rest of the day when they run out of boiled water from the morning hours. Thus, the potential of SODIS for people who already boil their water can be seen in replacing those couple of glasses of untreated water a lot of them consume in the afternoon.

Bought drinks are consumed throughout the day and there is no special pattern discernible.

4. Factors influencing the use of SODIS

In order to gain knowledge about what factors influence the percentage of SODIS-treated water on the total amount of consumed liquids a multiple regression analysis was carried out. The percentage of SODIS-treated-water on the total amount of consumed liquids was considered the dependent variable and it was calculated what influence the various independent variables from our questionnaire had on the dependent variable.
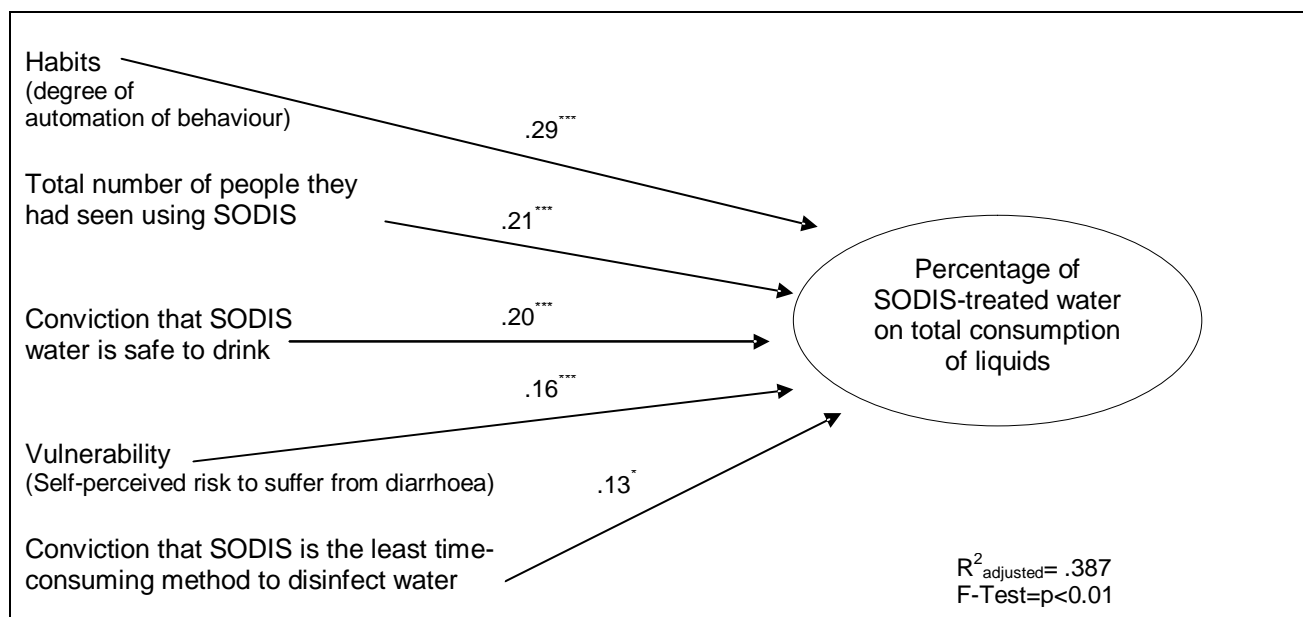

Figure 6: Regression analysis with Percentage of SODIS-treated water on total consumption of liquids as a dependant variable

The regression in figure 6 allows to determine how much effect the independent variables have on the dependent variable (percentage of SODIS-treated water on total consumption of liquids). The regression shows that habits influence the dependent variable (ß=.29) the most. A habit is the degree of automation of behaviour. We asked the people if they used SODIS more or less automatically or if they often forgot to put the bottles outside in the morning. Further significant influences on the percentage of SODIS-treated water on the total amount of consumed liquids are the total number of people they had seen using SODIS (ß=.21), the conviction that SODIS-treated water is safe to drink (ß=.20), the estimated vulnerability, which means the self-perceived risk to suffer from diarrhoea (ß=.16) and the conviction that SODIS is the least time-consuming method to disinfect water (ß=.13).

$R^2_{adjusted}$ indicates that 38.7% of the variance of the percentage of SODIS-treated water on the total amount of consumed liquids is explained by the five above-mentioned independent variables.
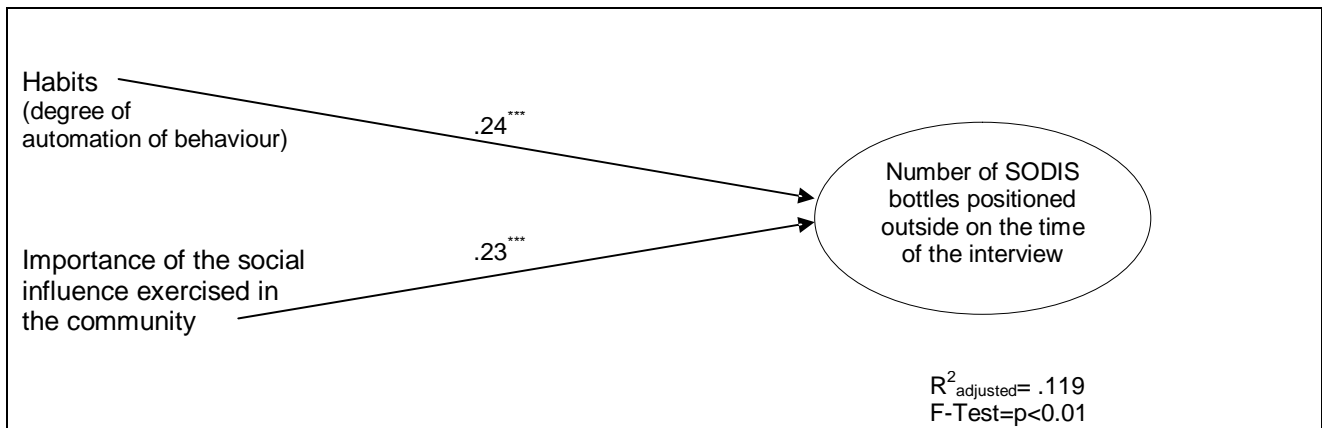

Figure 8: Regression analysis with number of SODIS bottles (per person) positioned outside on the time of the interview

For the regression analysis illustrated in figure 8, the number of SODIS bottles per person positioned outside at the time of the interview was taken as the dependant variable. Because this variable is part of our observational data it can be regarded as particularly objective and free of the possible distortions of self-reported data. Nonetheless, habits turn again out to be the most important predictive variable (ß=.24). The second variable is the importance of the social influence exercised in the community on the person (ß=.23). To determine the importance of the social influence exercised in the community, we asked the persons what their neighbours and friends would think about them if they drank untreated water.

$R^2_{adjusted}$ indicates that 11.9% of the variation in numbers of SODIS bottles per person put outside on the time of the interview is explained by the two above-mentioned independent variables.
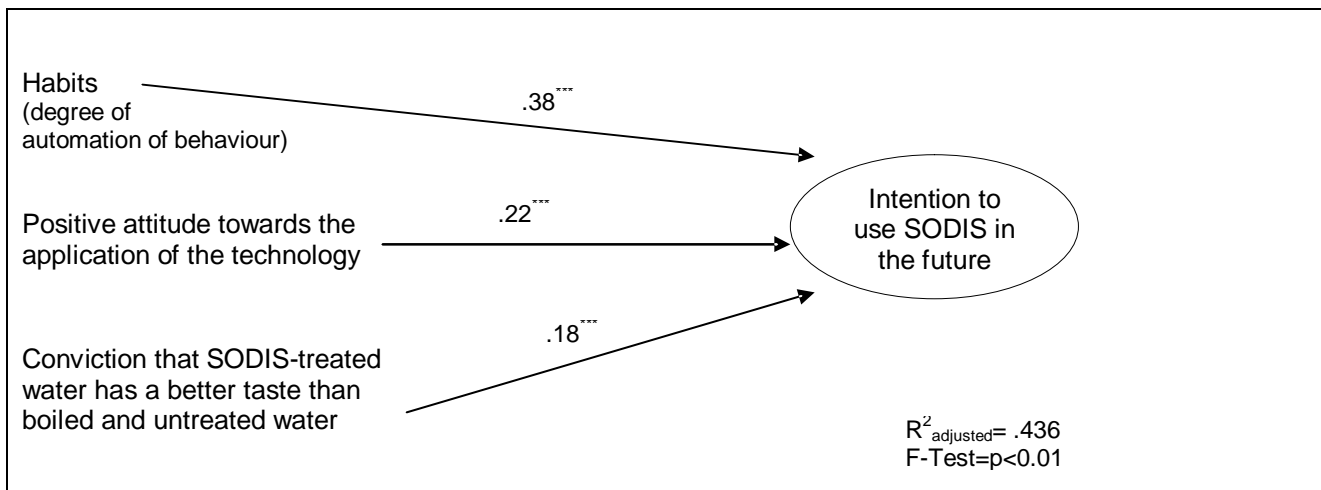
Figure 8: Regression analysis with intention to use SODIS as dependent variable

Another regression analysis was calculated in order to determine which variables influence the intention to use SODIS in the future and are illustrated in figure 8. The habit was again found to influence the SODIS-related behaviour significantly ($\beta=.38$). Unlike in the regression analysis in the previous paragraph, a positive attitude towards the application of the technology ($\beta=.22$) showed a great impact. Additionally, the conviction that SODIS-treated water had a better taste than boiled and untreated water ($\beta=.18$) resulted to influence the intention to use SODIS in the future in a statistically significant way.

$R^2_{adjusted}$ indicates that 43.6% of the variance of the intention to use SODIS in the future is explained by the three above-mentioned independent variables.

5. Influences of SODIS on health

5.1. Differences in diarrhoea incidence

The incidence of diarrhoea in the week preceding the interview was recorded in order to determine whether in our sample SODIS users suffered less from diarrhoea than people who drank untreated water. Indeed, as figure 9 reveals, a considerable difference can be found in the incidence of diarrhoea in the week preceding the interview. People who drank at least 70% SODIS-treated water (n=50) suffered, on average, from 0.6 days of diarrhoea episodes in the week preceding the interview, while people who drank at least 70% untreated water (n=22) suffered on average only 0.24 days of diarrhoea episodes in the week preceding the interview.
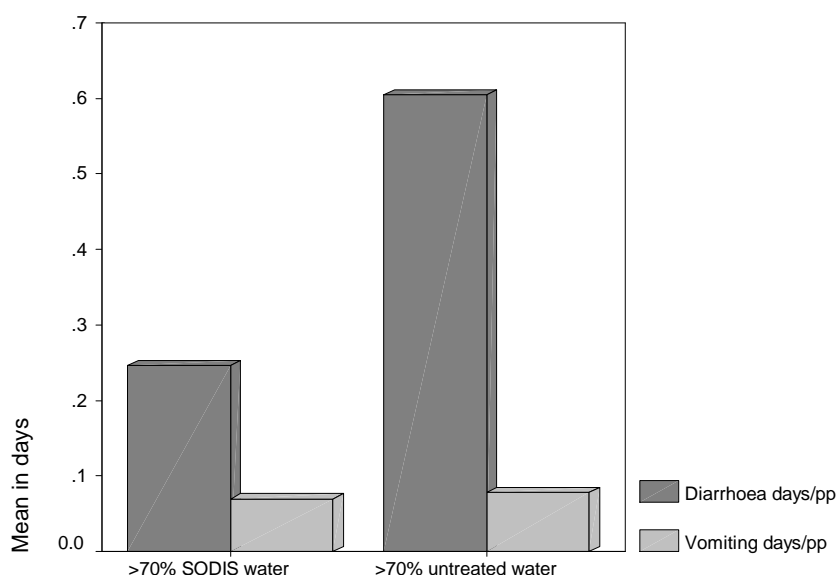

Figure 9: Incidence of diarrhoea and vomiting in the week preceding the interview (mean in days per person)

Moreover, the lower incidence in diarrhoea that was reported by the people who drank at least 70% SODIS-treated water is statistically significant (p=0.043) meaning that the difference between the two groups is not pure coincidence. It has to be considered that in our sample the two groups also differ significantly in their maintenance of hygiene, e.g. in the cleaning of their hands before eating and handling food, in the use of soap, in the observed cleanliness of the glass in which the requested water was served as well as the observation of the cleanliness of the hands of the interviewed persons. The conclusion from this fact is double, on one hand it cannot be interpreted in statistical terms that the use of SODIS is the sole reason for the lower incidence rate recorded, as this lower rate could also have been caused by the other diarrhoea-diminishing behaviours. On the other

hand, the results show that people who maintain a high level of general hygiene do also more often use SODIS. This finding is consistent with the endeavours undertaken by the different NGOs not only to promote SODIS but to include the technology of SODIS in their water, sanitation, and health programmes in order to enhance the general hygiene conditions and thus not only combating the consumption of contaminated water but all possible sources of diarrhoea.

The slightly lower incidence of vomiting in the group of people who drank at least 70% SODIS-treated water is not statistically significant and therefore must be attributed to coincidence.

5.2. Self-reported reduction in diarrhoea due to SODIS-use

Furthermore, the people who reported to use SODIS had been asked whether they had perceived a decrease in diarrhoea occurrence since they had started to purify their water with SODIS. The self-perceived diminution of diarrhoea is considered an important aspect in maintaining the behaviour of purifying the water with SODIS. We found a highly significant correlation of 0.21 between the self-reported reduction in diarrhoea and the percentage of SODIS-treated water on the total amount of consumed liquids. That means that people who perceive a high reduction of diarrhoea also consume more SODIS-treated water. As shown in figure 10 only 3% stated that they had not noticed any reduction at all. 4.7% reported that they felt a small reduction had taken place whereas 33.6% perceived a medium-sized reduction in diarrhoea and the great majority of 58.7% of all SODIS users reported that the use of SODIS had greatly reduced the incidences of diarrhoea.
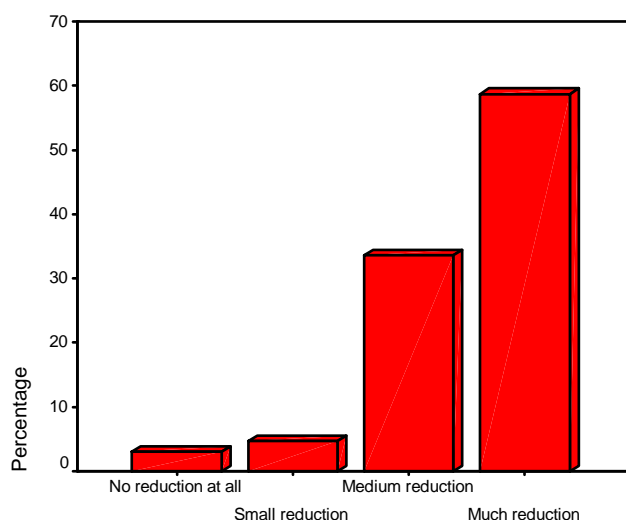

Figure 10: Self-reported reduction of diarrhoea due to SODIS-use

6. Evaluation of the different diffusion strategies

In this last section of the result chapters, an evaluation of the different promotion strategies which had been performed in the different investigation areas is presented. In order to evaluate the different promotion strategies, people were asked where they had heard or seen promotion for SODIS in their community and what kind of activities in connection with SODIS had been realized in their community.

About 3 different types of promotion strategies exist which had been used in our investigation areas. The first types are *household visits*. These had been performed by people of the SODIS Foundation, by people of the partner NGOs (PCI, UNICEF, CEPAC, CENPOSEP), by local authorities (UTIM) or by health promoters (volunteers of the health centres). A second type of promotion strategies were *official events*, namely health fairs, information in community or neighbourhood assemblies, information in existing groups (like the women groups) and in centres (health centre, mother's centre), programmes in schools for pupils or information events by health Brigades (brigadistas de salud).The last type of strategy was the use of *mass media*, like radio or TV transmissions, advertisements in newspapers and the distribution of promotion materials (stickers, calendars and so on).

Of course, not all of these promotion strategies had been performed in all of the investigation areas. A detailed description of the percentage of people who had attended a strategy by investigation area can be found in table 6. Numbers of participants of more than 10% are printed in bold. A considerable difference in the number of strategies that reach this diffusion mark exists between the different investigation areas. For example, in Alto Sebastian Pagador, Yapacaní, Potosí San Gerardo, and Villa Tunari, only two of the promotion strategies reached more than 10% of the interviewed families. In Alto Sebastian Pagador these are the house visits of the staff from the SODIS Foundation and the programmes in the school, in Yapacaní they are the visits from the staff of the NGO and the mass media promotion programmes over the radio. In San Gerardo, the district of Potosí where no active promotion strategies had been carried out, most people had heard of SODIS from the television or radio. In Villa Tunari, where the SODIS promotion started only half a year before our investigation was carried out, the radio and the visits of the health brigades reached more than 10% of our interviewed persons. In Uncía four, in

Tiraque and in Potosí San Pedro five promotion strategies reached more than 10% of the interviewed households and in Caripuyo as much as eleven.

Table 6: Percentage of people who had attended a promotion strategy by investigation area. Marked are strategies that reached more than 10% of the interviewed families in the area.

	Alto Sebastian Pagador	Tiraque	Yapacaní	Potosí San Pedro	Potosí San Gerardo	Uncía	Caripuyo	Villa Tunari
Local Promoters	1.3%	**12.5%**	2.3%	5%	0%	**13.2%**	**40%**	0%
Person of the SODIS Foundation	**38.8%**	**27.5%**	1.2%	6.3%	0%	1.3%	**22.5%**	1.3%
Person of the NGO	3.8%	**20%**	**52.3%**	**53.8%**	1.3%	7.9%	**76.3%**	**13.8%**
Local authorities	0%	1.3%	0%	1.3%	0%	**75%**	**15%**	0%
School	**10%**	8.8%	4.6%	1.3%	0%	1.3%	**31.3%**	1.3%
Health fair	1.3%	5%	2.3%	8.8%	2.5%	1.3%	**33.8%**	0%
Women's group	1.3%	25%	5.8%	3.8%	2.5%	5.3%	**15%**	0%
Centre for mothers	0%	7.5%	2.3%	3.8%	1.3%	5.3%	**20%**	0%
Assemblies	6.3%	**11.3%**	8.1%	**10%**	2.5%	23.7%	28.8%	1.3%
Radio	7.5%	**16.3%**	37.2%	**75%**	47.5%	39.5%	53.8%	**15%**
TV	6.3%	5%	0%	**68.8%**	46.3%	0%	2.5%	0%
Advertisement	0%	0%	0%	2.5%	0%	0%	1.3%	1.3%
Materials	0%	2.5%	4.6%	**27.5%**	1.3%	5.3%	**22.5%**	1.3%
Other strategies	1.3%	0%	0%	0%	3.8%	0%	0%	1.3%

Interesting in relation with these results is the fact, that a high positive correlation of 0.65 ($\alpha < 0.05$) exists between the average number of strategies people had participated on and the size of the information rate in the area. Therefore, the more strategies a person on average had actively participated in, the larger the number of people who knew about SODIS in the area is.

In addition, people were asked to value each of these strategies (or rather the person performing the strategy) according to their **liking**, **similarity** of opinions, persuasiveness **(quality of arguments)** and the delivered **quantity of arguments**. Furthermore, they were asked how many times they had participated on diffusion events (**frequency**), how the **atmosphere** was on these events (from very serious/formal to very cheerful) and if there was a **pro SODIS majority** of the people present. To compare the different strategies, standardized means of each of these attributes per investigation area were calculated. Then, for each attribute the means were added up over the different strategies and afterwards the attributes were arranged in order of the size of their added up means.

The ranking of the attributes can be found in the bottom line of table 7. Based on the valuation the interviewed gave each strategy, the ranks can be interpreted as to how good these features were covered in the promotion strategies.

Table 7: Evaluation of the different diffusion strategies by their attributes

	Argument Quality	Argument Quantity	Atmosphere	Liking	Similarity	Pro SODIS Majority	Frequency of participation	Rank
Health fair	+	+ +	+ +	+	+	+ +	- -	1
Local Authorities	+	+	+	+	+ +		+	2
Staff of the NGO	++	+	+	+ +	+		-	3
School	+	+	+	+	+	+	-	4
Local Promoters	+	+	-	+	+		-	5
TV	-	+	-	-	+		+ +	6
Women's group	-	-	-	-	-	+	+	7
Staff of the Foundation	+	+	-	+	-		-	8
Centre for mothers	-	-	+	-	+	+	-	9
Radio	- -	- -	- -	- -	- -		+	10
Community assembly	-	-	-	-	-	- -	-	11
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	

Ranking of the attributes over the promotion strategies was done by comparing each mean in the row with the overall mean of the attribute
++ = the highest mean of the attribute over the promotion strategies / + = means higher than the overall mean / - = means lower than the overall mean / - - = the lowest mean

As illustrated in table 7, the interviewed persons rated the quality of the arguments very highly (rank 1), followed by the quantity of the arguments (rank 2). Also the atmosphere on the different promotion events was rated as quite cheerful (rank 3) and the promoting person was valued as quite likable (rank 4). Rather bad was the perceived similarity between opinions of the promotion persons and the interviewed (rank 5), which could mean that the interviewed person had some difficulties identifying themselves with the promoting person. In need of improvement are also the work with majorities (rank 6) and the frequency of the events (rank 7).

Furthermore, the standardized means of the attributes were added up over each promotion strategy. Thus, a ranking of the strategies became possible. This rank can be interpreted as to how positive the interviewed person rated the strategy in comparison with

the other strategies (in regard to the before mentioned attributes). The ranks are shown in the last row of table 7.

People gave the best score to the health fairs, followed by promotion events (house visits) from staff of the local authorities, NGOs and local promoters. The programmes in the school and the TV transmissions also reached high ranks. However promotions in the women's group and mother centres; and promotions from the staff of the SODIS Foundation are in the lowest ranking. Radio transmissions and the promotions in the community assemblies also achieved poor ranks.

In a last step the standardized means of each attribute were compared among the strategies (the means of one column of table 7 were compared over the lines). Thus, the results were categorized in one of the four following groups. (++) was given to the highest mean, (+) was given to all means higher than the overall mean, (-) was given to all means lying under this overall mean and (- -) was given to the lowest result. If we consider for example the argument quality in table 7 (second row), the investigated persons rated the arguments given by the staff of the NGOs as the best, the arguments transmitted by the radio as the worst. The arguments given by health fairs, local authorities, school, local promoters and staff of the foundation were considered to be good, arguments transmitted by TV, women's group, mother's centre and community assemblies as rather bad. This evaluation allows a description of strengths and weaknesses of each promotion strategy. By identifying the weaknesses, the strategies could be improved in the future in these features.

Strengths of the health fairs for example are a high argument quantity, a very cheerful atmosphere and also that people perceived pro SODIS majorities. However a big weakness of health fairs is that they take place very rarely. Furthermore the argument quality, liking and similarity are positively valuated by the interviewed people. A detailed overview can be found in table 7. In the following part, the results are only reviewed briefly.

The strength of a promotion with help of local authorities is the highly perceived similarity of opinions which allows a good identification with the promotion persons. All the other attributes are valuated positively as well. The promotion by persons of the NGO was highly rated in the argument quality and the liking of the promotion persons, but the visits are, in

comparison with other strategies not frequent enough. Promotion programmes in schools were rated positively with the exception of the frequency, but do not reach any special strength.

Both promotions by NGOs and by local promoters do not take place frequently enough and the atmosphere of the visits was valuated as being rather formal. A considerable strength of promotion by TV is the high frequency by which people can be reached. It is interesting that also the argument quantity and similarity are positively valuated. Argument quality, atmosphere and liking however could still be improved.

The following promotion strategies were given a low positive valuation. In the women's groups the interviewed persons had frequented, neither the arguments, nor the promoting people, nor did the atmosphere seem to be good, although these groups took place quite often. Similar results were achieved by the SODIS Foundation staff and the centre for mothers.

Unfortunately radio transmissions received very poor ratings. Regarding the high diffusion radius of the radio, which for many isolated communities is the only possible promotion strategy with high frequency, the content of the transmissions should definitively be improved.

The promotion in community assemblies, which achieved just low to very low ratings, should be reconsidered and improved, for example by creating a pro SODIS atmosphere.

7. Summary and recommendations

The present survey examined what factors influence a household's decision to adopt or reject the technology of solar water disinfection. Furthermore, the promotion strategies on eight different investigation areas were evaluated in order to decide which strategy or combination of strategies foster the diffusion of SODIS the best.

In the present study we described the different adoption rates of SODIS-treated water in the investigation areas, consumption patterns of other liquids and the consumption of water during the course of the day. Furthermore, factors which influence the consumption of SODIS-treated water and the intention to use SODIS in the future were presented and the relation of the consumption of SODIS on diarrhoea was described. In a last section, the different SODIS promotion strategies, which had been performed up until now, were evaluated.

Naturally, the implementation of our investigation implies several potential weaknesses, which have to be considered when the data is interpreted. A possible restriction lies in the fact that a major part of our data is self-reported, which means that the persons interviewed had to make a self-assessment about the different aspects of their SODIS consumption behaviour. Self-reported data contain the possible danger that the interviewed persons tried to answer in a manner to please the interviewer (or the SODIS Foundation or the local organisation who promoted SODIS in the area) or to present themselves in a positive light. This answer tendency could even been reinforced by our cooperation with the local organisations who had promoted SODIS in the different investigation areas. Thus, potential manipulation of the interviewed through these organisations is possible. However, we are convinced that the investigation would not have been possible without the cooperation of the local organisation and that their help was very sincere and supporting. To avoid a 'socially desired answer tendency' the questions were, if possible, formulated in a way to cover our investigation intentions and different observation measures (for example the exposed bottles, the availability of SODIS-treated water, the hygiene of the interviewed and so on) were added.

A further problem lies in the fact, that the data was not collected by the authors of the present study but by a team of interviewers. The interviewers were trained and supervised

by the authors of the present study. Nevertheless, it cannot be excluded that the interviewers did not develop different tendencies of categorising the answers.

Despite these restrictions, our findings can give important clues to which messages should be stressed in future diffusion activities. As described in section 3.2 and 3.3, the drinking water consumption behaviour in Bolivia is rather complex. People consume boiled water, untreated water, SODIS-treated water and bought drinks at different times of the day. The aim of the promotion of SODIS is to increase the amount of safe drinking water consumed and not to replace already applied disinfection methods such as boiling. Thus, our first recommendation is to…

- ***Analyse the water consumption behaviour before selecting a new promotion area***

It is important to pay attention to the percentage of untreated water on the whole consumption when selecting the promotion areas. SODIS should with preference be diffused in areas with a high percentage of untreated water and not in areas with a high percentage of boiled water. For people who only partially consume treated water (for example boiled water) in their daily intake, SODIS presents a supplementing method to increase the percentage of safe drinking water consumed. As could be seen in figure 3 and 4, SODIS-treated water is mostly consumed in the afternoons and evenings, after the water which had been boiled in the morning was finished. Thus, a further recommendation is to…

- ***Support people in reorganizing their water preparation and consumption behaviour during their daily routine***

…in a way that SODIS-treated water is available when it is needed. For a family who boil their water in the morning SODIS-bottles should be placed outside just after sunrise in order to be ready in the afternoon. For households who do not boil their water it is advisable to prepare the SODIS water on the preceding day and store it over night in order to have safe drinking water available already in the morning. Considering the results from chapter 4, the integration of the preparation of SODIS in a way that does not interfere with the daily housework routine is crucial. As illustrated in figures 5 and 6, the grade of

automation (habits) exerts the strongest influence on the percentage of SODIS-treated water on the total consumption of liquids, as well as on the intention to use SODIS in the future. Unfortunately, the altering of existing habits and the development of a new habit are very difficult and normally take several months or even years. Thus, our next recommendation is to…

- ***Accompany people regularly over a long time period and reduce possible factors which disturb the process of the development of a new habit***

Possible disturbing factors should be discussed with the people and sustainable solutions should be developed fitting the varying needs and circumstances of different households and communities. The most cited reasons in our survey for not using SODIS or having stopped using it were due to lack of time (24%), cold or rainy weather periods (14%) and lack of sufficient bottles (13%). As the lack of time can be overcome by the smooth integration of SODIS into the daily task routines and the weather cannot be changed we suggest that another major factor in the development of using SODIS as a habit is the…

- ***Availability of sufficient bottles***

If bottles are delivered by the local organisations, as was the case in the major part of our investigation areas, emphasis should be placed on a regular and sufficient delivery of bottles, so that also several days of bad weather or lack of sunshine could be managed through reserves. Maybe it would be even more efficient to deliver a small number of households with sufficient bottles (until a stable habit of SODIS use is built) rather than a large area but only sporadically. Another possibility is to support and supervise the people of a neighbourhood or community in their own organisation of the collection and delivery of bottles.

Furthermore, people should be instructed and supported with materials which allow a correct maintenance of the bottles to extend their 'lifespan' and they should be instructed to keep bottles outside the reach of children who like to play with them. People who do not have taps at their disposal report discomfort to fill the cold water into the bottles, a possible solution could be to distribute or to instruct them how to make funnels.

Besides the habit, emphasis should be placed on the…

- ***Social exchange over SODIS in the communities***

As can be seen in figure 6, the more people have seen other persons using SODIS, the higher the percentage of SODIS-treated water on the total consumption of liquids becomes. This insight could be used in exposing SODIS bottles on highly frequented and well visible places (e.g. schools, health centres, community houses, but also in the houses of the mayors, teachers, promoters and so on). Furthermore, the communication about SODIS should be stimulated in a way that people know who else in the community uses SODIS.

Further emphasis should be placed on the attitudes people have towards the application as well as on the conviction that untreated water causes diarrhoea (increase of the vulnerability) and that SODIS water is safe to drink. The fact that the perceived taste of the water influences the intention to use SODIS in the future opens opportunities to win even more SODIS user by improving the taste of the water (for example by instructing people how to prepare aromatised drinks).

Concerning the promotion strategies which had been applied up until now, we saw a good realization of the rational arguments, which were highly valuated by the interviewed people, but a rather poor implementation of the frequency and pro SODIS majority. Regarding the fact, that habits were found to influence the SODIS-related behaviour in a consistently strong and significant way, it has to be considered that a unique event will have little effect on the habits whereas household visits with regular follow-ups would enhance the possibility of altering existing habits, which correspond to our third recommendation. The work with majorities can be improved by considering our fifth recommendation (increase the social exchange).

Thus, the present study enlightened several social psychological factors which influence the use of SODIS in different areas of Bolivia. Clearly, our analysis is not conclusive and other factors may exist. Further studies investigating the reasons that influence people to use SODIS or not in different cultures should be conducted.

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