
35th WEDC International Conference, Loughborough, UK, 2011

THE FUTURE OF WATER, SANITATION AND HYGIENE:
INNOVATION, ADAPTATION AND ENGAGEMENT IN A CHANGING WORLD

**Drivers of sustainable use
of solar water disinfection in Bolivia**

A. Tamas, Switzerland

REFEREED PAPER 1196

The current study investigates 12 former projects promoting Household Water Treatment and Safe storage (HWTS) in Bolivia with the aim to define the sustainable impact on people's level of HWTS use and factors influencing its long-term application. Data were collected from 785 households using structured interviews. According to the results obtained, 43–83% of the population use solar water disinfection (SODIS) and 16–79% use boiling as a water treatment option 1–4 years after project completion. However, since 25–86% of the people still consume untreated water, follow-up campaigns should be conducted in some areas. Based on the individual factors influencing SODIS use, future campaigns in mainly rural areas should team up with government institutions, target people's emotions and intentions to treat water, support habit development, and make use of social norms.

Introduction

Every year, 1.4 million people, mainly children under the age of five, die of diarrhoea (Prüss-Üstün et al., 2008). Roughly one third of diarrhoeal diseases in developing countries are caused by contaminated drinking water. Point-of-use water treatment at the household level becomes essential in places lacking central and safe water supply systems. HWTS methods, such as Solar Water Disinfection (SODIS), reveal a great potential for reducing the diarrhoeal disease burden. Comprehensive microbiological research has revealed the effectiveness of SODIS in destroying diarrhoea-causing pathogens in contaminated drinking water. Several health impact studies have shown a 16–57% drop in the incidence of diarrhoea among SODIS users.

Promotional activities for SODIS in Bolivia were launched in 2000. One year after project implementing of the SODIS method at grassroots (household) level, usually 40–80% of the trained people are still using SODIS regularly. In numerous cases, non-government organisations (NGO) report that the SODIS method is not self-promoting after its initial introduction into a community, though a few cases of self-dissemination have been observed after launching a SODIS promotion activity. No information is yet available on continued long-term field application of SODIS. To bridge this knowledge gap, the presented project aims at assessing the level of sustained SODIS use in Bolivia several years after project completion. Possible factors influencing SODIS use have been investigated and defined as external influences as well as internal motives responsible for driving individual water consumption behaviours. This paper relates these individual factors to individual behaviours, namely to the consistent use of SODIS. The knowledge acquired can be used to adapt future SODIS promotion and dissemination strategies to the local partners in Bolivia and other countries exhibiting similar conditions.

The external and internal factors analysed in this paper have been derived from psychological theories of behavioural change: (1) external: SODIS promotion strategies and local conditions and (2) internal: individual motivations for SODIS use. People's internal motivations are conceptualised as a set of individual beliefs related to water consumption, namely, a) risk, b) attitudinal, c) normative, d) control and e) maintenance beliefs. The underlying model can be found elsewhere (Tamas, submitted). The current paper tackles the following research questions: Which previous promotion campaigns and local conditions lead to

increased SODIS use? How strongly is SODIS water consumption driven by different beliefs, i.e. where do SODIS non-users and users differ most?

Methods

Selection of study area

Bolivia is one of the poorest countries in Latin America, with 63% of its 9 million population living below the national poverty line. The indigenous inhabitants, making up two thirds of the country's population, live mostly in the Andean valleys and Altiplano region, many in extreme poverty. This accounts for infant mortality twice as high as in similar low-poverty populations of Bolivia (WHO, 2007).

Since 2001, the SODIS Foundation (Fundación SODIS), based in Cochabamba, Bolivia, is actively promoting SODIS and other HWTS options in Bolivia; often in areas inhabited by the aforementioned underserved populations. Major NGOs and government agencies working in the water and health sector in Bolivia have accepted SODIS as a valuable complement to their ongoing HWTS programmes. Since most include the method in their daily activities, they are regarded as important local SODIS promotion partners of the SODIS Foundation. The present study collected data in Bolivia from 12 matured HWTS promotion projects implemented by the SODIS Foundation. These projects focused on the promotion of four HWTS options: filter, boiling, SODIS, and chlorination. SODIS was a particularly promising, novel and often unknown treatment method, since filter units and chlorination products were not available then in rural areas of Bolivia. To boil their water, people often used wood, a scarce resource in the Andean highlands. In contrast, the sun is generally an abundant resource, and fruit juice or soft-drink bottles are readily available at local markets. The campaigns were similarly structured in all investigated projects: a number of promoters were identified, mostly marginally incentivised volunteers who received training by the technical staff of the SODIS Foundation. Household or sometimes community trainings were subsequently carried out in the sparsely populated areas. After these trainings, follow-up household visits were conducted roughly once a month.

The investigated projects were mainly located in the high altitude rural areas of Bolivia. The study used combinations of four different selection criteria to identify the target communities: 1) end of project (from 2004 to 2008), 2) project duration (from 1 to 3 years), 3) implementing organisation (various NGOs or government institutions), and 4) urbanisation level (rural or peri-urban). The income level was similar in all project communities and data was collected in 52 different villages. The reason for the high number of villages is attributed to their small size. Apart from one case, we interviewed 50–100 households in each investigated project as summarised in Table 1.

Project No.	Promotion year	Promotion time (years)	Region / District	Implementing organisation		Urbanisation	No. of households
				Name	Type		
1	2001–2004	3	Potosi	CENPOSEP	NGO	peri-urban	71
2	2004–2005	1	Ocuri	IPTK	NGO	rural	72
3	2004–2005	1	Patacamaya	Caritas Corocoro	NGO	rural	58
4	2005–2006	1	Chayantaka	PDA Chayantaka	NGO	rural	76
5	2005–2007	2	Soracachi	PDA Soracachi	NGO	rural	49
6	2005–2006	1	Caripuyo	PCI Oruro	NGO	rural	68
7	2005–2007	2	Llallagua	Municipio de Llallagua	Gov.	rural	44
8	2005–2007	2	Caranavi	PDA Caranavi	NGO	peri-urban	88

TAMAS

9	2006–2007	1	Cochabamba	PDA Nueva Esperanza	NGO	peri-urban	35
10	2007–2008	1	Zudañez	SEDES Chuquisaca	Gov.	rural	92
11	2005–2008	3	Uncia	Municipio de Uncia	Gov.	rural	75
12	2007–2008	1	Pocoata	Municipio de Pocoata	Gov.	rural	57

Note: NGO = non-government organisation, Gov. = government.

Measurement

Since many inhabitants of the investigated areas are illiterate, questionnaires were used to collect data in structured interviews. A team of trained and supervised Bolivian interviewers conducted the interviews in Spanish or Quechua, depending on the participant's preference. The questionnaire was developed on the basis of previous experience (e.g. Tamas et al., 2009; Tamas, 2009) and discussions with the local partners. Concurrence in understanding the interview questions was ensured and application of the questionnaire was trained during role-playing with the interviewers. Some parts of the questionnaire focused on household demographics, water consumption, beliefs related to risks associated with water, attitudes, social norms, and HWTS use habits. The questions asked in this questionnaire are listed herewith:

- Water consumption behaviour: Did you consume untreated, boiled, filtered, SODIS, chlorinated, or any other water during the last 2 weeks? (0=no, 1=yes). How much of untreated, boiled, filtered, SODIS, chlorinated, or any other water did you and your family consume yesterday? (The answer was usually given in cups and later converted into percentages of 100; 0=0%, 100=100%).
- Danger of diarrhoea for young children: How dangerous is diarrhoea for young children? (0=not dangerous, 4=very dangerous).
- SODIS knowledge: Interviewer, please rate the level of knowledge on a given scale. (0=no knowledge, 4=very good knowledge).
- Liking, tastiness and healthiness of SODIS water: Scale of 3 correlated items (Cronbach's Alpha = 0.90): Do you like or dislike drinking SODIS water? Do you think SODIS water tastes good or bad? Do you think SODIS water is good or bad for your health? (-4=very negative affect, 4=very positive affect).
- Time and effort of preparing SODIS water: Do you think preparing SODIS water costs a lot of time and effort? (0=no time & effort, 4=a lot of time & effort).
- Monetary costs of SODIS water: Do you think SODIS bottles cost a lot or little money? (0=no money, 4=a lot of money).
- Availability of bottles: Are bottles easily available? (0=never available, 4=always available).
- Social status of SODIS: How do other people think of you if you drink SODIS water? (-4=think very badly of me, 4=think very good of me).
- Social norm of SODIS: Please estimate, how many people in your village drink SODIS water? (0=nobody uses it, 4=everybody uses it).
- Intention to drink SODIS in the near future: How much SODIS water do you intend to drink in the near future (next month)? (0=nothing, 4=100%).
- Habit of drinking SODIS water: Is drinking SODIS water a habit for you? (0=no habit, 4=a very strong habit).

Sample selection and characteristics

Interviews were conducted with the households, particularly with family members responsible for drinking water. Since they were randomly distributed across the respective community areas, the interviewers were advised to ensure a representative selection of households across their respective interview areas. In the often very small and widespread rural communities, almost every household, present at the time of the visit, was interviewed. In larger rural and peri-urban communities, interviewers were advised to interview every third household. Timing of the interviews seemed to pose a problem. The visits usually started around midday due to travel time to reach the villages. However, most inhabitants of rural areas work in the fields at

that time. Local authorities previously announced the survey only in a few of the visited areas. Yet, merely a negligible number of households, present at the time of the visit, refused to be interviewed.

Of the final 785 households sampled, 75% live in rural and 25% in peri-urban areas. Almost two thirds of the interviewed are female (64%). The current mean age is 40 years (SD=14.5) and, on average, the interviewed person had attended school for 4.7 years (SD=4.5). The average household size numbers 4.9 persons (SD=2.2); 51% have at least one child below or equal to 5 years. Most people (92%) have access to a tap, but not necessarily located inside the house. Other minor water sources used by the households are unprotected wells (2%), protected wells (4%), springwater (2%), river or lakes (2%). Education level, varying on average from only 2.5 years in Ocuri to 8.7 years in Caranavi, differs significantly between projects. Minor, but still significant differences between projects relate to aspects of gender and age of the interviewed person and household size.

Analyses

Water consumption patterns were analysed using descriptive statistics. Project characteristics and demographic figures, related to HWTS use, were examined using univariate (if not stated otherwise) logistic regressions on SODIS use, boiling or consumption of untreated water. Individual motivations of treating water related to SODIS use was analysed using a multivariate logistic regression on SODIS non-use vs use. The main outcomes from the logistic regressions are odds ratios (OR) and their lower and upper 95% confidence intervals given in brackets [].

Results

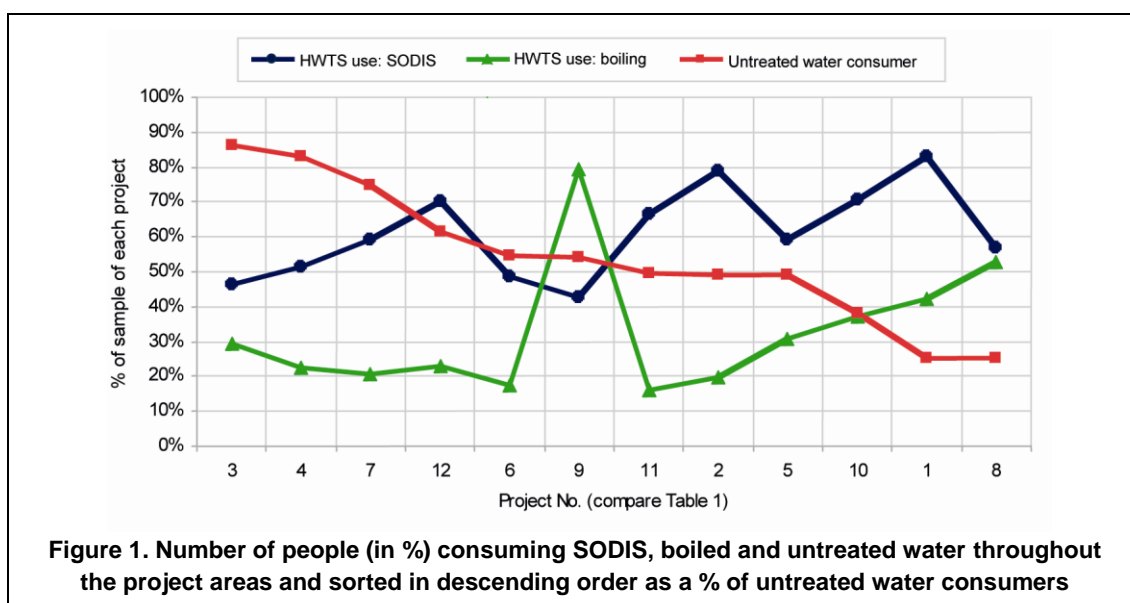
Water consumption pattern

Despite the satisfying outcome of the study on HWTS use, consumption of untreated water is still fairly widespread. On average and across all 12 projects, 62% of the population consumes SODIS water (range: 43–85%), 31% use boiling not only for tea or coffee, but also for water treatment (range: 16–79%), 3% purchase water (range: 0–14%), and 52% consume untreated water (range: 25–86%). Nobody uses filter or chlorine products. An overlap was observed between untreated water consumers and HWTS users: 30% of the sampled households use both. As a rule, the more people use water treatment; the lower the percentage of untreated water consumers, despite the observed significant differences between the various projects. Details of all 12 projects are illustrated in Figure 1. Most consumed water is boiled (44%, including tea and coffee), followed by SODIS water (30%) and untreated water (25%). The amount of purchased water is negligible (1%).

Project characteristics in relation to HWTS

Significant differences were observed between the various projects. Some of the differences in untreated water consumption and HWTS user rates can be related to certain project characteristics:

- The three projects with the highest boiling rates were observed in peri-urban areas as opposed to rural areas, where boiling is less prevalent (OR=3.62[2.57; 5.09]).
- Untreated water consumption is lower in peri-urban than in rural areas (OR=0.30[0.22; 0.43]).
- SODIS use is equally spread in rural and peri-urban areas (OR=1.08[0.77; 1.52]).
- Government promotion achieved higher rates of SODIS users than NGO promotion (OR=1.41[1.03; 1.92]).
- Project duration relates positively to the proportion of SODIS users (OR=1.29[1.06; 1.56]), even if controlled for the year the project ended (OR=1.28[1.06; 1.55]).
- Reciprocally, the longer the project lasted, the less people consumed untreated water (OR=0.61[0.51; 0.74], controlled for the year the project ended).
- Project duration had no influence on water boiling.



Demographic indicators in relation to HWTS use

The demographic indicators of the sample were already provided with sample description. The following factors relate to water consumption:

- People with a higher education are somewhat less likely to consume untreated water (OR=0.95[0.92; 0.98]) and SODIS water (OR=0.96[0.93; 1.00]), but more likely to boil water for water treatment (OR=1.06[1.02; 1.10]).
- Men are more likely to consume untreated water than women (OR=1.65[1.23; 2.22]) and less likely to use SODIS (OR=0.71[0.53; 0.96]) and boiling for water treatment (OR=0.58[0.42; 0.80]).
- Larger households are more likely to use SODIS than smaller ones (OR=1.10[1.03; 1.18]).
- Households with children under 5, and the age of the interviewed person have no influence on water consumption.

Individual motivations for treating water in relation to SODIS use

SODIS is the only HWTS method used aside from water boiling. However, boiling is not seen as an environmentally sustainable option. Also, boiling is practiced mostly in peri-urban areas where people use gas and not wood for water boiling. Therefore, particular focus was placed on the drivers of SODIS use as an alternative HWTS method, especially in rural areas. Simultaneous multivariate odds ratios were calculated for individual motivations determining SODIS use, controlled for demographic characteristics.

Table 2 contains all the mean values for SODIS non-users and users, including odds ratios (OR) for being a SODIS user compared to a non-user. The results in Table 2 can be summarised as follows: Compared to SODIS users, non-users exhibit a lower education level, are more aware that diarrhoea can constitute a danger to young children, are better informed about SODIS, generally prefer SODIS for its taste and health effects, perceive the preparation of SODIS as less time and effort-consuming, regard SODIS as socially higher-ranking, perceive the social norm of SODIS use as higher, stronger intend to use SODIS in the future, and perceive the preparation of SODIS water more as a habit. Only the perceived costs and availability of SODIS bottles concur among SODIS users and non-users – bottles are perceived as readily available at low cost. The multivariate odds mainly reflect these differences. Based on the selected indicators, 71% of the variance, relating to the reason why a household uses SODIS, can be explained.

Despite the significant differences in some indicators among SODIS non-users and users, the mean values of both groups indicate a high awareness of the dangers of diarrhoea to young children. Likewise, SODIS knowledge is quite high also among SODIS non-users, and SODIS is not perceived as very time and effort consuming. Conversely, the social status of SODIS is quite low even among SODIS users.

Table 2. Mean values of SODIS non-users and users, including multivariate odds of relevant demographic figures and beliefs related to HWTS and SODIS use.						
Indicator	Descriptive statistics		Multivariate logistic regression statistics			
	Mean SODIS non-users	Mean SODIS users	OR	Lower CI	Upper CI	p
Gender (woman=0, man=1)	0.40	0.33	0.65	0.33	1.27	.206
Education (years)	6.17	4.44	0.94	0.87	1.01	.077
Household size (people/HH)	4.95	5.03	1.03	0.89	1.20	.670
Danger of diarrhoea for young children	2.91	3.43	1.57	1.09	2.25	.015
SODIS knowledge	2.76	3.34	0.58	0.38	0.87	.009
Liking, tastiness and healthiness of SODIS water	1.44	3.04	1.76	1.28	2.44	.001
Time and effort of preparing SODIS water	1.35	0.75	0.71	0.52	0.97	.033
Monetary costs of SODIS water	0.66	0.70	1.28	0.84	1.94	.250
Availability of bottles	2.58	2.53	0.97	0.71	1.31	.832
Social status of SODIS	0.35	1.03	1.53	1.07	2.20	.021
Social norm of SODIS	1.30	2.23	0.93	0.58	1.48	.752
Intention to drink SODIS in the near future	1.14	2.87	1.80	1.20	2.72	.005
Habit of drinking SODIS water	0.85	2.93	3.90	2.63	5.77	.000

Variance: Cox and Snell $R^2 = 0.47$, Nagelkerke $R^2 = 0.71$. N=560 due to missing values.

Note: Independent variables wording and units are given in "Measurement". Dependent variable coding: SODIS non-use = 0, SODIS use = 1. OR = odds ratio, CI = 95% confidence intervals of OR, p = significance level. Bold OR are significant at $p < 0.05$ level.

Discussion

The current study investigated 12 former HWTS promotion projects conducted between 2001 and 2008. The main HWTS options, used by the investigated population, include water boiling (31%) and solar water disinfection (SODIS; 62%). Moreover, 52% of the population still consume untreated water. The average figure of 62% long-term SODIS users is quite impressive, given the fact that prior to the start of these projects in the mainly very remote areas the population was only familiar with water boiling and not with SODIS. The study not only aimed at investigating the current status of HWTS use, but also at determining the factors influencing HWTS use.

While promotion activities lasted 1–3 years, the projects were completed between 2004 and 2008. The longer a project, the more likely SODIS was used and less likely untreated water was consumed by the households. The increased chance of using SODIS amounts 28% per year of promotion activities, however, chances to consume untreated water reveal a higher decrease of 39%. During campaigns, focus should be placed more on decreasing consumption of untreated water as: a) there is a stronger potential for influence and b) only if untreated water consumption is stopped entirely, positive health effects can be expected (e.g. Waddington et al., 2009). The time of project completion had no influence and confirmed the measured, true long-term effects that are unlikely to change in the future.

Most of the investigated projects, located in the rural areas of the Andean highlands, are characterised by their difficult access and poor infrastructure. Moreover, three peri-urban projects were also investigated. Mainly due to the regular supply of gas bottles, it is not surprising that boiling is far more common in peri-urban areas where less people consume untreated water. This may be attributed to an overall higher exposure to health issues and/or HWTS-related information in schools, health posts and other public places. Interestingly, SODIS is similarly widespread in peri-urban and rural areas. In rural areas, it possibly serves to replace untreated water, as increased boiling is not a sustainable option for reasons of firewood scarcity. However, in peri-urban areas it could, to some extent, even replace boiling since the available gas bottles are often perceived as quite costly.

A factor of key interest for most organisations looking for implementing partners at local level is the question whether government organisations or local NGOs are the more efficient collaborating institutions. In the present case, after project completion of a government-supported promotion project compared to a NGO-supported project, the households turned out to be 41% more likely to use SODIS while no difference was observed for boiling and untreated water use. The success of government-assisted projects may be partly attributed to the normally larger and more locally based government networks. This is particularly useful when focusing on rural and sparsely populated areas. NGOs, in contrast, may first have to create their local networks.

Investigations of the drivers of SODIS use were conducted, as SODIS is the only HWTS method used aside from boiling, which is rather practiced in peri-urban areas. A set of internal motivations or beliefs was found to be related to the use of SODIS. It is not surprising that the degree of habit was the most powerful driver of SODIS use, i.e. habit-driven SODIS application increases its likelihood of being used. What seems tautological at first can be used for designing future interventions. Habit development is often lacking and should be considered in HWTS promotion projects. Habit interventions can be simple and easily applied, for example, placing simple reminders will help people remember to use a new HWTS method (Tamas, 2009; reminder in other contexts e.g. Cox et al., 2005). Also, planning a new behaviour where it best fits into people's daily routines and linking it to already existing habits will help establish new behaviours and turn them into habits. Aside from other factors, targeting habit is important, as it will help bridge the well-known gap between internal motivations and actual behaviour (Schwarzer, 2008).

In addition to habit, other factors were observed to be important drivers of SODIS use, especially perceived liking, tastiness and healthiness of SODIS water, as well as the intention to use it should be increased among SODIS non-users. During promotion projects, positive emotional links should be established to make people feel good and comfortable when using a new HWTS – they should *like* the idea of consuming the treated water. Likewise, negative links to consuming untreated water could be made. Positive emotions around HWTS should be evoked, for example, letting people taste the water, creating a positive atmosphere during a promotion campaign, and turning health into a positive feeling rather than a rational physiological condition. Rational health arguments often do not have the desired effect, as perceived healthiness of a water type is a more affectively driven factor than a rational evaluation. Intentions can be enhanced and commitments increased by using explicit oral or written statements.

Though the difference between SODIS non-users and users with regard to the social status of SODIS is important enough to be a significant factor, the low value of the social status of SODIS for both groups was a surprise. A link to the status of SODIS can probably be established based on the perceived social norm, which was also observed to be pretty low. One reason may be the low population density in the investigated areas. People who barely see the next house are unlikely to notice if other people use HWTS. Consequently, a social norm based on visibility will hardly be able to establish a new behaviour. Here, campaigns should use other measures in addition to the individual household visits to increase the salience of existing social norms. Possibly a type of small event assembling all the villagers to exchange their experiences with HWTS use could be useful in raising people's awareness of other people's behaviour, and in establishing whether HWTS has reached some kind of positive status within the community.

Conclusion

The current study draws three main conclusions: 1. Promotion of HWTS, especially the use of SODIS, had a measurable and sustainable impact on the affected communities. Efforts should be sustained, even with low population density and difficult accessibility. 2. Continued efforts can be channelled through government institutions. Especially in sparsely populated rural areas, government institutions reach far more people. Municipal structures are well suited; health structures should be explored further since only one project has

been conducted together with the prevailing health system. 3. Studying drivers of HWTS use at individual level will help enhance the understanding of designing future campaigns. For example, campaigns promoting HWTS use should focus increasingly on: a) eliciting positive emotions from target populations relating to water treatment rather than using rational arguments on health risks and benefits; b) making people state their commitment in a more formal way to bridge the gap between positive intentions and behavioural practice; c) supporting habit development with specifically designed interventions like small reminders or recurring household visits; and d) initiating group activities to give HWTS use a social dimension and make use of normative influences among community members.

Acknowledgements

The author wishes to thank the Fundación SODIS for its support in Bolivia and Katharina Wojtalla for providing parts of the data for this paper.

References

- Cox, C. D., Cox, B. S., & Cox, D. J. (2005) *Long-term benefits of prompts to use safety belts among drivers exiting senior communities*. *Journal of Applied Behavior Analysis* Vol. 38, No 4, pp.533–536.
- Schwarzer, R. (2008) *Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors*. *Applied Psychology: An International Review* Vol. 57, No 1, pp.1–29.
- Prüss-Üstün, A., Bos, R., Gore, F., & Bartram, J. (2008) *Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health*. Geneva: WHO.
- Tamas, A. (2009) *Successful promotion of Solar Water Disinfection (SODIS)*. PhD Thesis, University of Zurich, Zurich.
- Tamas, A. (submitted) *Achieving sustainable behaviour change: long-term effects of household water treatment promotion strategies in Nepal*. *Journal of Water, Sanitation and Hygiene for Development*.
- Tamas, A., Tobias, R. and Mosler, H.-J. (2009) *Promotion of Solar Water Disinfection: Comparing the effectiveness of different strategies in a longitudinal field study in Bolivia*. *Health Communication* Vol. 24, No 8, pp.711–722.
- Waddington, H., Snilstveit, B., White, H. and Fewtrell, L. (2009) *Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries*. International Initiative for Impact Evaluation.
- World Health Organisation (2007) *Country cooperation strategy at a glance: Bolivia*. Retrieved January 31, 2011, from http://www.who.int/countryfocus/cooperation_strategy/ccsbrief_bol_en.pdf

Contact details

Andrea Tamas
Ueberlandstrasse 133
P.O. Box 611
CH – 8600 Duebendorf
Switzerland.
Tel.: +41 44 823 54 60
Email: <mailto:andrea.tamas@eawag.ch>
Homepage: www.eawag.ch
