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Original Research

Achieving long-term use of solar water disinfection in Zimbabwe

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SUMMARY

Objectives: To use a psychological theory of behavioural change to measure and interpret the effectiveness of different promotional strategies for achieving long-term usage of a household water treatment and safe storage (HWTS) system in peri-urban Zimbabwe.
Study design: Solar disinfection (SODIS) was introduced into five peri-urban communities near Harare, Zimbabwe. Six different interventions were developed and were applied in four communities in different combinations, with the fifth remaining as a control area where no interventions were implemented.
Methods: Throughout the 26 months of the study nine longitudinal panel surveys were conducted in which SODIS usage was estimated using three separate metrics: reported, calculated, and observed. A total of 1551 people were interviewed.
Results: The three indicators of SODIS usage broadly agreed with one another. By any measure, the most effective intervention was household visits by trained promoters in combination with persuasion. Households which received household visits maintained SODIS usage rates of 65% or more, even six months after the cessation of all promotional activities. Households receiving other interventions were significantly less effective. Interventions like prompts or public commitment after the application of household visits were effective at maintaining good practices once these were established.
Conclusions: Household promotion in combination with persuasion appears more effective than other approaches, especially when followed with interventions targeting the maintenance of the new behaviour. With this intervention it is possible that around 65% of the households continue to use solar water disinfection (SODIS) more than two years after the initial promotion, and six months after the end of all interventions.

Introduction

There is compelling evidence that household water treatment can reduce pathogen levels in drinking water and lead to lower reported rates of diarrhoeal disease, even in the absence of sanitation or hygiene improvements.[1,2] Household water treatment and safe storage (HWTS) systems can be inexpensive, making them highly cost-competitive compared to

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construction of improved water supplies.[3] Accordingly, WHO, UNICEF, and others have increased efforts to scale up the promotion of HWTS in recent years.

However, the reported health impacts have been challenged due to the strong possibility of respondent bias, which can lead to inaccurate reporting of treatment practices and diarrhoeal disease prevalence.[4] This challenge applies to measuring behaviours as well as health impacts: the discrepancy between self-reported behaviour and actual practice is well known in many fields, including handwashing with soap[5,6] as well as household water treatment.[7,8]

Even if robust indicators indicate that an intervention has led to household water treatment and improved health, there is little evidence about the long-term sustainability of such gains, especially if subsidized or free material was provided during promotional phases. Some evidence suggests that improvements may be ephemeral. In Pakistan, an intensive intervention led to a dramatic increase in handwashing with soap, and a sharp reduction in both diarrhoea and respiratory disease.[9] However, a follow-up study 18 months after the intervention ended found higher levels of knowledge in intervention households, but no difference in soap consumption or diarrhoeal disease.[10] An evaluation of a combined water treatment/handwashing intervention in Guatemala, made 6 months after the end of the intervention, found no difference in self-reported diarrhoeal prevalence, though intervention households were slightly more likely to practice household water treatment (boiling or solar disinfection).[7]

Adoption of an HWTS system is a process of behavioural change which has to be induced with interventions which target behavioural factors. Mosler describes in his RANAS Model (Risk, Attitudes, Norms, Abilities, and Self-Regulation) the relevant behavioural factors and their correspondent behaviour change techniques (interventions).[11]

Risk factors are divided into perceived vulnerability, a person's subjective perception of his or her risk of contracting a disease, and perceived severity, a person's perception of the seriousness of the consequences of contracting a disease. Information interventions aim to increase the risk perceptions of people about the health impacts of drinking untreated water.

Attitudinal factors comprise cost/benefit (e.g. how time consuming the behaviour is) and affective (e.g. taste and temperature of the treated drinking water) evaluations. Attitudes can be changed with persuasive arguments which use causal explanations, explain functionality, present novel and important information, and are of high positive expectancy value. Attitudes can also be changed by inducing a dissonance-like tension by confronting people with their discrepancy between their attitudes and their behaviour.

Normative factors comprise the descriptive norm (perceptions of which behaviours are typically performed by others), and the injunctive norm (perceptions of which behaviours are typically approved or disapproved by important others). Perceived social norms can be influenced by informing about others' approval/disapproval: knowing that important others support the desired behaviour or disapprove the unhealthy behaviour is an important motivator to comply. Also a public commitment may change social norms: people make their obligation to a favourable behaviour public thus showing to others that there are people who perform the new behaviour.

The *ability* factors are represented by self-efficacy, which is the belief in one's capabilities to organize and execute the course of actions required, and action knowledge, i.e. knowing how to perform the behaviour. Self-efficacy can be fostered by guided practice, such as skill demonstration, instruction, and role play with feedback.

Finally, *self-regulation* factors refer to aspects of putting a behaviour into practice and maintaining it. To perform a behaviour continuously, the person has to be committed to doing so and the behaviour needs to be remembered at critical moments. Interventions targeting self-regulation include implementation intentions by specifying when, where, and how the person will practice the new behaviour. Memory prompts can help remind people not to forget the new behaviour. Such interventions can help translate goals into actions by preventing people from becoming distracted, falling back into bad habits, or failing to get started.

These behavioural factors represent all significant drivers of health behaviour change and are a compilation of factors from the Theory of Planned Behaviour[12] and from the Health Action Process Approach.[13] A more detailed description of the behavioural factors can be found in Mosler (2012).[11] The RANAS factors have been used to explain behaviour regarding consumption of safe drinking water in several cross-sectional studies.[14,15]

While many studies investigate behavioural change, few ground interpretation of behavioural change in psychological theory, or compare the relative power of different interventions and communication channels. In this manuscript, we use the RANAS framework to analyse the impact of different behavioural interventions combined with different interpersonal communication channels upon uptake of a household water treatment system (solar disinfection, SODIS) in peri-urban settlements of Zimbabwe. Behavioural interventions were made in series, with repeated measurements of SODIS use by households, in order to measure the impact of different interventions, as well as long-term effects of behaviour change. In order to address the potential of respondent bias in self-reported compliance, we assess three alternative indicators of SODIS use.

Methods

Research area

Field research was carried out in Epworth township and Hopley farm, two peri-urban settlements near Harare, Zimbabwe. Sanitation and hygiene practices in these areas are poor, and most people drink untreated water which is microbially contaminated.[16]

From these two settlements, five geographically separated clusters were identified and 878 households selected for interviews: 364 households in two clusters (numbers 1 and 2) from Hopley Farm, and 514 households in three clusters (numbers 3–5) from Epworth. Households were chosen by means of systematic route sampling, in which interviewers went to every third household on their way through their

assigned area.[17] In all cases, the survey respondent was the person responsible for the drinking water of the members of the household, and gave informed consent prior to the interview.

Interventions

A variety of interventions were made to improve different psychological factors related to uptake and sustainable use of SODIS. In total, six different forms of interventions have been tested in different areas in several combinations. A series of four separate intervention phases were implemented, each followed by a panel survey to assess effectiveness (see Fig. 1). Each panel survey was used to choose an appropriate next intervention for each area, depending on which psychological factors were least positive. Different sequences of interventions were made in each area, with area 5 used as a control area. However, after the last panel, those interventions which proved most useful (e.g. household promotion) were employed for two months in area 5, to ensure fairness.

Baseline survey & information events

SODIS information events were held in all five areas in April 2007. In all areas, bottle centres were established and run by trained SODIS promoters, who sell (used) plastic bottles and inform buyers about SODIS. Though any kind of transparent plastic bottle can be used for SODIS, the poor availability of bottles in general make the bottle centres a potentially successful business idea.

Intervention 1 (October–November 2007)

Two different interventions were chosen to encourage adoption of SODIS: household visits and a pass-on-task in combination with persuasive arguments. In household visits, trained promoters go from household to household discussing with residents to advocate for an innovation.[18] The pass-on-task is a strategy where community members are selected and trained to perform a task dedicated to their social network. These persons try to convince their neighbours, acquaintances and friends, and encourage them to in turn convince others, generating a 'snowball effect'. Both interventions can be considered to affect risk perceptions and attitudes, as well as perceptions of injunctive norms. Supposedly, pass-on tasks additionally may influence perceptions of descriptive normative behaviours, because people receive information from other people about something they do (and very likely approve of).

Areas 1 and 2 received information and persuasive communication through household visits done by trained promoters who were inhabitants of the project areas. Visual aids included low-literacy flyers which showed pictures on how to use SODIS and listed its advantages such as health improvements, low cost, and good taste. Households were visited once, or in some cases twice, for approximately 30 min.

Areas 3 and 4 received the same information and persuasive communication delivered by means of a pass-on-task. Promoters visited one in five households in the two areas, providing information about SODIS over 30 min. Household members were then asked to pass on the information to someone else (the "pass-on-task"). They received a token with which they could obtain a transparent plastic bottle for half price at a bottle centre. Whenever someone buys a bottle at the bottle centre, that person is informed about SODIS, given (another) token and asked to pass this token on to someone else and so forth.

Intervention 2 (March 2008)

Following the initial phase of SODIS adoption encouragement, different interventions were implemented to sustain or increase SODIS use.

Prompts and public commitment are memory aiding techniques which are widely and successfully used in environmental psychology for fostering self-regulation and social norms.[19,20] Both often appear in the form of signs (e.g. stickers, posters, cards) that remind the owner of a certain task.

In Area 1, stickers (prompts) were put up inside the house which showed a person putting up bottles on the roof and

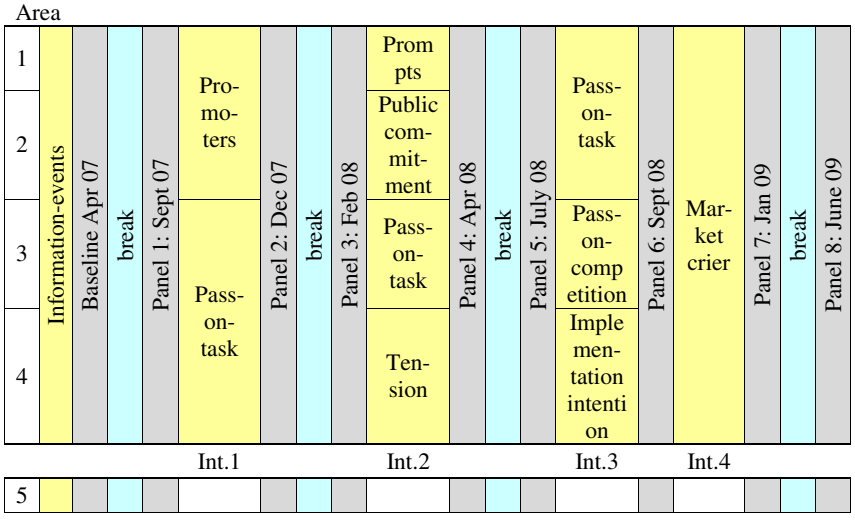

Fig. 1 – Intervention and survey schedule.

reading: "Have you put your bottles on the roof yet?" In Area 2, stickers were put on a prominent spot outside the home (public commitment) which read: "Here we use SODIS because it makes us healthy". In Area 3, the pass-on-task was used a second time. Brief household visits were made to every fifth household over the course of four weeks to promote the pass-on tasks.

Another strategy to improve attitudes is to induce tension by contrasting desirable behaviours with actual practices. This approach was applied by promoters in Area 4 who gave background knowledge on how water can be contaminated, how that can create illnesses and how these can be prevented, before asking: "Are you doing SODIS?" to induce tension.

Intervention 3 (August 2008)
Areas 1 and 2 received pass-on-tasks to test the effectiveness of this strategy in areas where use is already high. In Area 3, the pass-on-task was complemented by a competition. Each time a token was returned to a bottle centre, the user's name was entered into a lottery, with winners chosen after six weeks.

In Area 4 *implementation intention contracts* were used to stimulate integration of SODIS into daily routines and to foster self-regulation. Household members, with the help of promoters, filled out contracts stating exactly where and when the targeted behaviour was planned to be performed, with the aim of thereby increasing commitment.[21]

Intervention 4 (October 2008)
A *public crier* was employed in Areas 1–4: for several days, one or two people carried a large colourful poster about SODIS through local areas and read out persuasive scripts.

Intervention and survey summary

Over the course of two years one baseline and eight panel surveys were conducted in the five areas (see Fig. 1). Five surveys directly followed an intervention period; four were made after a gap of several months. 878 people were originally interviewed. Drop-out was low (usually under 10%) and 100 new people were recruited in each of the later panels, resulting in a final surveyed population of 1551.

Indicators of SODIS use

The use of any household water treatment is typically difficult to measure. Therefore, three different indicators are compared in the present study.

Self-reported practice: Survey respondents were asked: "Are you doing SODIS?" This question has four possible answers: (a) I am doing SODIS regularly, (b) I am doing SODIS sometimes or irregularly, (c) I have tried SODIS but stopped, and (d) I am not doing SODIS. Those people who answered (a) are classified as "self-reported users".

Calculated use of SODIS: Survey respondents gave quantitative information about their consumption of various kinds of beverages. From these responses, the enumerator could calculate the percentage that SODIS water constitutes of the overall consumption. Altherr *et al*. have shown that diarrhoeal disease reduction among under-five children was only realized when the calculated proportional use of treated drinking water was high.[22] Although this metric relies on self-reported information, it is considered less vulnerable to respondent bias than self-reported practice.

Observed practice: Interviewers observed the number of bottles they could find placed in the sun (usually on the roof) of the household they were visiting and indicated this number in the questionnaire. Households having bottles on the roof were considered as "observed users".

Statistical analysis

All of the following analyses have been conducted with the statistical program SPSS 19, with the exception of concordance analysis, which was made with Stata 11.0 (Stata Corporation; College Station, TX, USA).

Results

91% of survey respondents were female. The mean age was 32 (SD = 11.43, 13–86); the mean number of years of education was 8 (SD = 3.39, 0–16), and the mean monthly household income was 400,000 Zim$ (about US$ 15 at that time; SD = 654,623, 0–10,000,000). On average, each household has 4.5 members (SD = 1.82, 1–13), including one under-five child (SD = 0.86, 0–6). On average, people possess one to two bottles per person and use them daily or every two days. No significant differences were noted between intervention and control areas.

With five geographic areas and nine surveys 45 measures of reported, calculated and observed SODIS practice were collected. Of these three indicators, calculated and observed practice agreed most closely (Lin's concordance correlation coefficient = 0.815). The mean difference between calculated and observed use was 1.3%, with a 95% limit of agreement ranging from −41% to +39% (See Supplemental information for details).

Figs. 2–4 show the effectiveness of different interventions in stimulating and maintaining SODIS use, using each of these indicators. A general linear model was developed for the percentage of SODIS water consumption, which showed that the development of SODIS consumption changed significantly over time in all areas ($F = 270.37$, $p < 0.001$). Groups were significantly different from each other ($F = 42.70$, $p < 0.001$), and Bonferroni post-hoc tests reveal that pair-wise differences between all areas are significant ($p < 0.05$), except for areas 1 and 2, and areas 3 and 5, which do not significantly differ ($p > 0.05$). The interaction effect between groups over time is significant ($F = 145.13$, $p < 0.001$), meaning that the groups are developing differently.

The campaigns that could produce most SODIS users were those using household promoter visits in combination with persuasion (intervention 1 in areas 1 and 2). Self-reported and calculated use was quite similar in these areas, while observed practice also rose significantly, but after a lag period of several months (with no intervention).

Memory aids like prompts or public commitment (intervention 2, areas 1 and 2) were useful in maintaining high numbers of regular users.

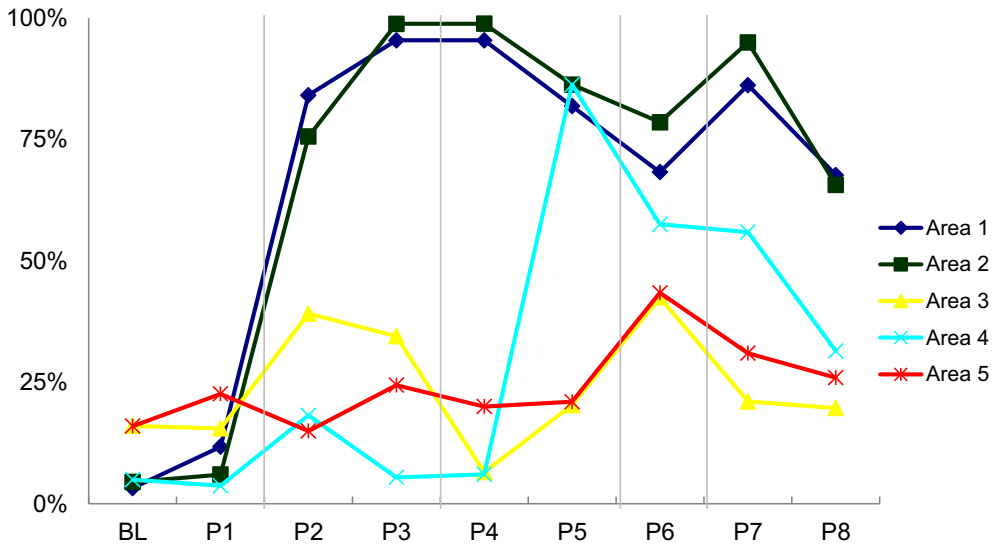

Fig. 2 – Proportion of respondents who report themselves as regular SODIS users at baseline (BL) and subsequent panel surveys (P1–P8). Interventions are marked with vertical lines.

Pass-on-tasks in combination with persuasion led to only moderate uptake when existing practice was low (intervention 1, areas 3 and 4), and actually decreased SODIS use when practice was high (intervention 2, area 3; intervention 3, areas 1 and 2). The pass-on-task with competition (intervention 3, area 3) did increase self-reported regular SODIS use, but both calculated and observed usage declined.

The strategy of inducing tension (intervention 2, area 4) immediately increased calculated and observed SODIS use; self-reported use also rose after a lag of several months.

The impact of the implementation intention intervention (intervention 3, area 4) is unclear: self-reported and observed SODIS use dropped after the intervention, while calculated usage rose moderately.

The public crier intervention seemed to maintain SODIS usage where practice was high (albeit with a lag in calculated usage), but had little or negative effect where SODIS practice was low.

Sustained practice, as assessed with the final panel survey after six months with no intervention, was mixed. Self-

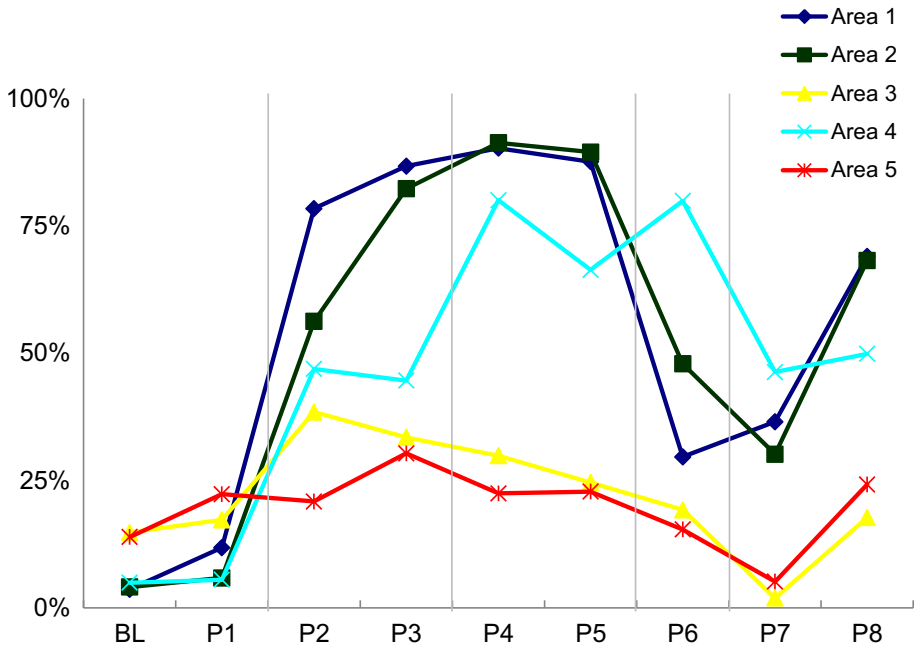

Fig. 3 – Mean calculated ratio of SODIS-treated water to total drinking water at baseline (BL) and subsequent panel surveys (P1–P8). Interventions are marked with vertical lines.

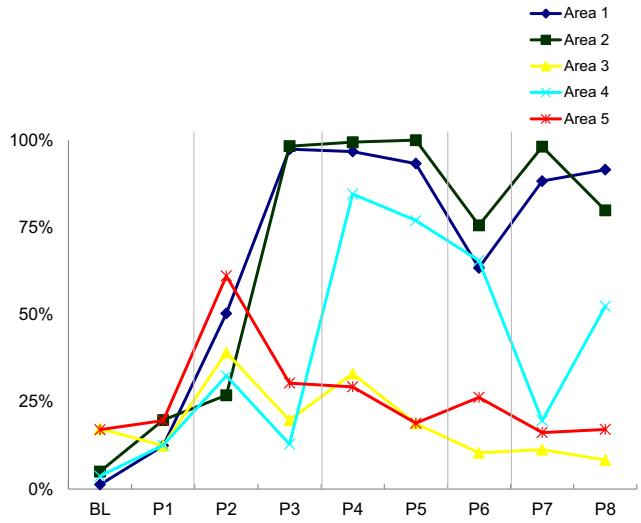

Fig. 4 – Proportion of households observed to have SODIS bottles in the sun at baseline (BL) and subsequent panel surveys (P1–P8). Interventions are marked with vertical lines.

reported usage declined in all areas after the gap, most markedly where practice was higher. However, calculated SODIS usage displayed exactly the opposite trend in all areas, while observed practice was mixed.

Discussion

Survey data demonstrate that household visits in combination with persuasion are by far the most successful interventions to establish the use of SODIS. By any of the three metrics, at least 65% of people who received household promotional visits were actively practicing SODIS more than two years after the initial promotion, and six months after the end of all interventions. These rates are significantly higher than other groups which did not receive household promotion. These findings are congruent with the work of Tamas *et al.* who found the deployment of promoters (household visits) superior to that of opinion leaders and health fairs in establishing SODIS usage.[23] The combination of pass-on tasks, followed by inducing tension (both of which also made use of household visits by promoters) led to similar increases in SODIS usage, though subsequent drop-off was greater.

Where new practices were established, usage could be maintained at high levels through simple prompts and public commitments. However, pass-on tasks were not effective at maintaining new habits, perhaps because the pass-on activity relates more to advocating behaviour change by others, rather than solidifying one's own new habit. When usage rates did drop, the simple intervention of a town crier was able to restore levels to high levels.

From these survey findings, the most promising intervention strategy is to initiate a new behaviour with household visits by trained promoters, but importantly to maintain the new behaviour through reminders such as prompts, public commitments or public criers. Household visits require a high level of human resources, which can be readily available for small scale research activities, but scaling up of household visits may be difficult for government agencies or local NGOs with limited human resources. Promotion through government agencies may take more time, but may allow more sustainable application of interventions, at larger scales.[24] Future research could investigate the practicality and effectiveness of including different degrees of intensity (e.g. number of household visits) in large-scale interventions by government agencies.

It is notable that in the control group from 10% to 25% of households were found to be SODIS users, using any of the three indicators. This shows that without any special intervention apart from information and follow-up surveys a small amount of people will accept an innovation. These people might be the early adopters in the sense of Rogers's concept of diffusion of innovations.[25] In contrast to other findings[26] these early adopters did not pass their SODIS practice on, and the proportion of SODIS users in the control group did not increase over time. Nevertheless, the usefulness of the diffusion of innovations approach has been demonstrated for the dissemination of SODIS in Bolivia.[27,28]

The three different indicators of HWTS adoption showed similar trends over time. This study was not able to determine which indicator was more accurate, but the strong correlation suggests that self-reported SODIS usage is a useful proxy for more labour-intensive indicators such as calculated or observed practice. These measurements differ regarding some practical aspects. Reported SODIS use would be greater than calculated use for people who consider themselves as regular users but perform SODIS only to a small extent and so consume only a small percentage of SODIS water. There also might be persons who consume a high percentage of SODIS water but do it only once a week with many bottles and therefore did not have bottles on the roof when observation took place.

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Ethical approval

All survey respondents gave informed written consent before participating in the study. Ethical approval has been attained from the Research Council of Zimbabwe (RCZ; permit number 02620).

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Competing interests

None declared.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.puhe.2012.09.001.