Review Paper

Socio-psychological determinants for safe drinking water consumption behaviors: a multi-country review

Jonathan Lilje and Hans-Joachim Mosler

ABSTRACT

The effectiveness of household water treatment practices relies heavily on consumers' compliance. However, what is driving these behaviors from a health psychological perspective is not well understood. A review of studies on safe water collection, treatment, handling and storage practices was conducted to identify important socio-psychological determinants. The objectives are to show which determinants commonly explain safe water consumption practices and how well they do so, and to identify behavior- and population-specific determinants to be targeted in different contexts. The results of the review reveal that all the practices studied can be explained well, with a mean of 62% explained variance between performers and non-performers. Social norms, action knowledge, and perceived self-efficacy were shown to be the most common influential factors for safe water practices. Instrumental beliefs around costs and benefits as well as affective beliefs such as taste are important in a majority of cases but varied more strongly, both for different target behaviors and between specific settings and populations, and are thus to be evaluated from case to case. The review gives clear recommendations on which behavioral factors to address with priority and corresponding behavior change techniques to be made use of in contexts where formative research is not possible.

Key words | behavior change, behavioral determinants, developing countries, drinking water treatment, health promotion, health psychology

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INTRODUCTION

One of the major risk factors for diarrheal diseases is inadequate drinking water. According to a systematic review of data from 145 low- and middle-income settings (Prüss-Ustün *et al.* 2014), the burden of disease related to water of insufficient quality was estimated to exceed one-third of all of diarrheal deaths within the population (population attributable fraction) in many parts of the developing world, or approximately half a million cases in low- and middle-income countries in 2012.

Household water treatment and safe storage (HWTS) practices are the most promising instruments to increase water quality at the point-of-use (POU) (Wolf *et al.* 2014). Options include boiling, mechanical filtration, and chemical (chlorine) and physical (solar) disinfection in combination with safe storage. While the provision of an improved water source alone is no guarantee of water quality (Bain *et al.* 2014), HWTS at the point of final consumption bypasses the problem of recontamination during storage and prior to consumption (Mintz *et al.* 1995; Wright *et al.* 2004; Rufener *et al.* 2010). Significant reductions of diarrheal prevalence can be expected from HWTS usage, and it is one of the most important means for prevention (Arnold & Colford 2007; Clasen *et al.* 2007; Cairncross *et al.* 2010). Securing the quality of water at the source level or switching to safe(r)

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water sources, where available, can also increase the quality of water consumed in settings where the origin of drinking water poses a significant risk. One example of this is the case of arsenic-contaminated wells in Bangladesh (van Geen *et al.* 2002).

Of all these approaches, POU treatment has been most widely researched from the perspective of behavioral change, with few exceptions, as a recent review demonstrates (Parker Fiebelkorn *et al.* 2012). POU treatment methods include disinfection with sodium hypochlorite, flocculent disinfectant, or chlorine; filtration with porous carbon block ceramic, or granular media water filters; boiling; solar water disinfection (SODIS); or various combinations of these methods. Despite ongoing discussions around the toxicity of chemical disinfection by-products (Smith *et al.* 2010; Luilo & Cabaniss 2011; Chu *et al.* 2015), current WHO guidelines for drinking water quality rate the risk of these by-products to be largely outweighed by their benefits, and therefore recommend treatment using chlorine within set dosage limits (World Health Organization 2011).

Whichever the chosen technology, the impact of HWTS interventions on consumers' health has been shown to depend significantly on their compliance and consistent usage (Clasen 2015). Even slight reductions in adherence to solely consuming safe water can have a negative impact of over 90% on the benefits expected. This means that drinking unsafe water even only occasionally can dramatically diminish the total health gains expected (Brown & Clasen 2012; Enger *et al.* 2013). Examples from several countries demonstrate that it is often not enough merely to provide infrastructure or technological methods to a population without further efforts to promote behavior change (Sonego *et al.* 2013). An understanding of the factors driving existing or desired alternative behaviors is consequently an essential prerequisite for fostering behavior change. Targeting the process of delivering interventions, and not just the products themselves, is seen as the key to success in future development work (World Bank Group 2015).

The process of designing successful behavior change campaigns demands an understanding of mindsets relating to a certain behavior or behavioral options so as to leverage behavior change. This can be done by identifying the socio-psychological factors which differ between those people who currently perform a desired behavior and those who fail to do so. Health psychology has identified a range of factors within the individual that steer health-related behaviors in specific situations. Factors that impact behavior and decide whether or not certain behaviors are adopted and maintained include personal risk evaluation, thoughts, attitudes, such as affective and economic assumptions about costs and benefits, societal norms, personal evaluations about being able to perform a behavior, and mechanisms transforming initial behaviors into habits (Abraham & Michie 2008; Michie *et al.* 2008; Bartholomew & Mullen 2011). This existing and well corroborated knowledge about socio-psychological drivers from health psychology can be used to explain and subsequently change behaviors related to safe drinking water consumption.

To date, the extent to which socio-psychological determinants can contribute to the understanding of different safe water practices is still unclear. A general comparison is lacking of studies conducted for drivers of different behavioral options in different geographical and socio-cultural contexts. Several studies have been published, but these only provide single pieces of evidence for specific populations and safe water practices. What is missing is an integrated synopsis of the influence of socio-psychological determinants on different safe water practices in various countries, populations, and settings. Therefore this review has four objectives:

1. To show whether socio-psychological factors can explain different safe water consumption practices sufficiently well.
2. To identify socio-psychological factors which are most probably useful for all safe water practices, in all environmental and sociocultural contexts.
3. To detect socio-psychological factors which are specific for different HWTS methods (SODIS, boiling, filtration, chlorination), switching to safer sources, and the hygienic handling and storage of water.
4. To identify socio-psychological factors which are probably specific for different populations.

Objective 1 is approached by looking at the explanatory power of socio-psychological factors for different safe water consumption practices. Objective 2 is met by looking at socio-psychological factors that are common for all safe

water practices in all environmental and socio-cultural contexts. Objective 3 is tackled by comparing the socio-psychological factors that determine different HWTS practices, and for Objective 4, socio-psychological factors for the same practices are compared between different populations.

By addressing these objectives, general conclusions can be drawn about the key factors to be tackled in campaigns to achieve behavioral change in general and for specific safe water behaviors in different socio-cultural settings, contexts, and countries.

METHODS

The goal of this review is to combine and compare the results of studies addressing safe water consumption practices and behavior change using socio-psychological factors. The studies concern different behavioral options for safe drinking water, including HWTS technologies, proper handling and storage of drinking water, source water quality monitoring, and switching to safe sources.

We conducted a title search in Web of Science and Scopus databases for relevant literature combining the three concepts of (drinking) water, treatment methods or common contaminants, and (psychological) behavior (theory). The exact search terms and combinations are listed in Table 1. The time range was restricted to articles published in 2000 or later. The references included studies and were hand searched for further potential entries.

Three reviews on the topic of behavior change related to safe drinking water technologies were identified among the literature searched (Parker Fiebelkorn *et al.* 2012; Dreibelbis *et al.* 2013; Hulland *et al.* 2015). Publications mentioned in these reviews were also examined for eligibility to fit into the scope of this review.

Inclusion criteria

Only studies that are based on a theoretical framework and explicitly mention socio-psychological behavioral factors related to safe drinking water options were included. The following additional requirements were set:

- the target behavior was clearly specified and addressed safe water consumption;
- the target behavior was used as a dependent variable to be predicted by a set of socio-psychological behavioral determinants;
- behavioral psychological theory or an appropriate framework was used to operationalize behavioral determinants;
- variable measurements were carried out quantitatively and used to predict the target behavior.

Classification of studies

Socio-psychological factors measured as determinants to explain targeted behaviors were extracted and classified on the basis of health-psychological theory. The studies are

Table 1 | Main concepts and search terms used for the literature review

Main concepts (combined with AND operator)	Water	Treatment/common contaminants	Behavior/(psychological) behavioral theory
Search terms/alternatives (combined with OR operator)	water drinking water	treatment disinfect* solar water disinfection SODIS chlorin* filt* boil* arsen* fluor	behavior* determinants *psycho* RANAS HAPA health action process approach health belief model social learning theory theory of reasoned action theory of planned behavior transtheoretical model use adoption consumption

Depicts a truncation, meaning for example that the term 'chlorin' will result in findings of chlorine, chlorination, etc.

listed systematically in Table S1 and are accompanied by the corresponding psychological constructs. We used the Risks, Attitudes, Norms, Ability, and Self-Regulation (RANAS) model for behavior change (Mosler 2012) as a template for analyzing these studies.

The RANAS model was developed specifically to examine behavioral determinants for water, sanitation, and hygiene (WASH) and environmental health practices in developing countries. It draws on a range of theories from health psychology, such as the health belief model (HBM; Rosenstock 1974), protection motivation theory (Floyd *et al.* 2000), Theory of Planned Behavior (Fishbein & Ajzen 2010), and the health action process approach (HAPA; Schwarzer 2008), and incorporates all the relevant factors in the health psychology literature. Distinct groups of behavioral determinants have been shown to be relevant for the prediction of health behavior, as described below. All five groups of factors should be considered to gain a comprehensive understanding of the psychological characteristics that determine specific behaviors within a population (Mosler 2012).

The risk determinants contain all the factors affecting an individual's understanding and awareness of health risks. *Perceived vulnerability* refers to the subjective awareness of the risk of contracting a disease. *Perceived severity* is the perception of the seriousness of the consequences of contracting a disease. *Health knowledge* refers to the understanding of how someone could be affected by a disease, for example, knowing the pathways for potential contamination with pathogens.

Attitudinal determinants express a positive or negative stance towards a behavior. *Instrumental beliefs* concerning a behavior include beliefs about monetary, timely, and personal efforts and gains, possible savings, and health consequences. Furthermore, attitudes have an affective component (*affective beliefs*) relating to feelings arising when someone performs or thinks about a behavior.

Normative factors represent perceived social pressures with respect to a particular behavior. They can be determined by observing the behavior of others (*descriptive norm*) and refer to perceptions of behaviors typically performed by others. In contrast, others' declarations of approval or disapproval (*injunctive norm*) reflect perceptions of behaviors typically supported or not supported by relatives, friends, or neighbors. Approval by others includes institutional norms, the dos and don'ts expressed by recognized authorities such as traditional and religious leaders and other institutionalized norms. Finally, the *personal norm* conveys what an individual believes she or he should do.

Ability determinants represent aptitudes that individuals believe they must possess to fulfill the desired behavior; they represent a person's confidence in being able to perform a behavior. One precondition, the how-to-do knowledge (*action knowledge*), is that the people concerned know how to perform the behavior. The perceived ability to perform (*self-efficacy*) corresponds to confidence in one's ability to organize and execute the courses of action required to manage situations in which the new behavior is required. The perceived ability to retain a new behavior (*maintenance self-efficacy*) includes beliefs about one's confidence in being able to deal with barriers that arise to keeping up the behavior. The perceived ability to rebound (*recovery self-efficacy*) describes one's confidence in recovering from setbacks.

Self-regulation determinants are responsible for the continuation and maintenance of a behavior; they help the person to manage conflicting goals and distracting cues when intending to implement and continue a behavior. *Action planning* represents ideas about how to set up the behavior by specifying its when, where, and how, and *action control* refers to strategies of ongoing monitoring and evaluation with regard to behavioral standards. Barrier planning (*coping planning*) means that the person has to have plans to overcome barriers that would impede the behavior. Finally, the person should remember the behavior in the right situation and has to be committed to performing it.

Table S1 shows the ensemble of behavioral determinants in the top row. All studies were classified and organized accordingly. The table reports authors, year of publication, psychological theories used, country in which the study took place, the targeted safe water behavior option, association between each psychological factor, and the target behavior for each study row by row. All factors were classified according to the template matrix and are listed in the table wherever they were reported. Studies are also grouped according to the type of safe water option. Nine studies concerned POU treatment options, four studies

dealt with switching sources, one study examined water quality testing in private wells, and one study looked at the hygienic handling and storage of drinking water. Operationalization of the constructs in each study with exemplary items can be followed in the Supplementary material (Table S2, available in the online version of this paper).

The results of the statistical analysis are classified into three categories for each individual factor and study. If the association between a factor and the target behavior was found to be significant, it is coded with a plus sign ('+'). Wherever no significant association was reported, the factor is coded with a zero ('o'). Not available ('n.a.') was recorded whenever a factor was not assessed or no results were given. Furthermore, sample size (N) and R^2 values are recorded for each study as a measure of the goodness of fit for the model in question. This parameter describes the explanatory power and comprises all factors included in a model to explain the variance in the targeted behavior. A summary is given under each section with the number of studies reporting a significant association, no association, and factors not reported. A mean R^2 value is also calculated. The last row shows the overall conclusion for all included studies. In addition, a reference is given where the reported results can be found in the original studies.

RESULTS

After removing duplicates, the literature search turned out 1,249 potentially relevant articles. Scanning all titles and abstracts where necessary, we retained 26 articles of potential interest. Six other studies were added after hand searching the identified literature including the references given in three reviews on the topic. Articles reporting on the same project and dataset were only included once (removal of six articles). Twelve studies were excluded because they either did not use psychological theory to operationalize behavioral determinants (3), did not measure quantitatively (2), did not correlate behavioral factors with the target behavior (3), or used only very few psychological concepts (4). Consequently, 14 studies conducted between 2000 and 2015 met the inclusion criteria and were thus included in this review. These used health-psychological theory to explain and predict key safe water consumption behaviors across eight developing countries in South America (Bolivia and Nicaragua), Africa (Benin, Chad, Ethiopia, Kenya, Zimbabwe), and South East Asia (Bangladesh), and one study was conducted in the USA.

Eight studies looked at POU HWTS options: five of them on SODIS, one on boiling, one on chlorination, and one on filter usage. Four studies addressed the question of switching to safe sources: one study was on the consumption of fluoride-free water from a community filter and three studies were on the usage of arsenic-free water sources. Another study looked at domestic well testing to monitor water quality. Hygienic handling of drinking water was examined in another study that looked at cleaning water storage containers. For a detailed list of all the studies included, refer to Table S1.

A few studies that did not meet the inclusion criteria shall be discussed shortly, and reasons given for their exclusion.

Rainey & Harding (2005) used the HBM (Rosenstock 1974) to examine the acceptability of SODIS in Nepal, operationalizing a range of behavioral factors. However, the interviews were qualitative and thus the results were not correlated with the target behavior, so no predictive value can be estimated for the behavior change potential.

McLennan (2000) also drew on the HBM to examine whether or not purely knowledge-based campaigns for promoting safe water treatment methods, such as boiling, would be successful and what other factors should be taken into account to promote this behavior. However, the model contains only four variables; a number of important factors, such as social norms, were not addressed at all, making the results difficult to include in this systematic comparison.

Another study surveyed the use of drinking water filters for arsenic removal in Bangladesh and asked respondents to rate the appearance, taste, and smell of the water, their perceived health condition after drinking filtered water, and whether they would recommend it to their neighbors (Ngai *et al.* 2007). While these variables certainly cover some relevant psychological concepts and give an idea of user perceptions, the responses were not correlated with current usage to explain adoption or non-adoption.

Wheeler & Agha (2013) assessed changes in some psychological factors in a longitudinal design concerning

POU water treatment in Mozambique. Knowledge about disease and associated behaviors as well as community norms, social support, and self-efficacy in the application of a chlorine-based water disinfectant were measured using agreement statements. Although they showed an increase in most of these factors following interventions, no distinction was made between users and non-users to examine the predictive power of these factors for the target behavior.

Moser & Mosler (2008) used the theory of diffusion innovation to examine the adoption of SODIS technology in Bolivia. However, only a few variables were included, in line with their theoretical approach of measuring determinants for behavioral adoption quantitatively and using them to predict behaviors.

Albeit explicitly using the RANAS model, significant differences in psychological factors between people who consume boiled water and those who do not were not used to calculate their predictive value for the target behavior in another study in Burundi (Sonego & Mosler 2013).

Although factors for safe water treatment and consumption behaviors were examined in all these studies, they were either not used to explain behavior or not treated in a systematic way that would allow comparisons with other studies. These studies were thus excluded from the review.

Another systematic review of factors affecting the sustained adoption of different WASH technologies identified quite a large number of studies conducted in the water sector (Hulland *et al.* 2015). The authors searched and listed psychological, contextual, and technological factors according to the integrated behavioral model for water, sanitation, and hygiene (IBM WASH; Dreibelbis *et al.* 2013). However, interest was rather in factors relating to the sustained use of the technologies rather than in determinants explaining differences between users and non-users, and the studies did not specifically focus on psychological determinants. A review of the studies included did not lead to any further entries into the present systematic overview.

For Objective 1 of this review, the results of the statistical regression analysis of the psychological determinants were examined for the prediction of different safe water consumption behaviors. They revealed a varying but consistently high quality of explanation; the average R^2 value is 0.617, with a range from 0.245 to 0.894. The mean R^2 for POU HWTS options is 0.607, and 0.685 for switching to safe sources. The study examining hygienic handling of drinking water yielded an R^2 of 0.625, and that on well testing an R^2 of 0.415.

In pursuit of Objective 2, we identified socio-psychological factors that were common for all safe water practices in all environmental and socio-cultural contexts. The summaries of cases in each column of Table S1 were compared for the number of significant and non-significant relationships between individual factors and the target behavior. Our results are described in order of the importance of the factors.

Instrumental and affective beliefs from the attitudinal component show significant associations with target behaviors in over half of the studies. These two factor blocks contribute to the explanatory power of the model in 57% of all cases where it has been assessed (8/14) for instrumental belief and in 64% (9/13; not assessed in one case) for affective beliefs. The perceived monetary and non-monetary costs (such as the additional effort of a longer walking distance to a source) are factors relevant to alternative behaviors within the instrumental belief determinant. The taste of treated water or the difference in taste between traditional and alternative safe water is one of the most frequent factors of relevance in affective beliefs. Descriptive norms explain an individual's choice of behavior in the majority of studies (71% or 10/13) and across several target behaviors.

Self-efficacy convictions contributed significantly to explaining safe water consumption behaviors in over half of all assessed cases (62%; 8/13). Maintenance and recovery self-efficacy were only explicitly looked at in detail in just two cases, where they returned significant results for maintenance in both cases, and for recovery self-efficacy in one case. Action knowledge about the target behavior showed a positive association in almost all of the assessed cases (80%; 4/5); however, it was not assessed in nine cases.

The other behavioral factors play only a minor role in determining safe water practices. Injunctive norms were found to be relevant in less than one-third (31% or 4/13) of the cases assessed. Personal norms played a role in one out of four studies where they were assessed, but were not assessed in nine cases. The three factors of the risk component contribute significant explanatory power in only a

minority of cases (30% of cases where there was an assessment for vulnerability, 25% for severity, and 27% for factual knowledge about disease and disease transmission).

Factors of the self-regulation component were not evaluated systematically in many of the projects, and few studies mention results relating to these. Action and coping planning were assessed in only three and four cases, respectively, where they did not add significant explanatory power for variations in any of the target behaviors. No data are available for the rest of the studies. Remembering/forgetting of a behavior to be performed yielded two significant contributions in the regression analysis and two non-significant results, but was not assessed in 10 studies. Commitment was evaluated in five studies, and significant contributions were found in three (60% of cases). Self-reported habit, operationalized as the perceived automaticity of execution, was identified as an important factor in five studies additionally. Habit is shown as an outcome in the RANAS model, but it can also be a determinant of behavior by provoking almost automatic behavioral reactions to stimulating situations (Tobias 2009).

To accomplish Objective 3, we tried to detect factors that are specific for different safe water practices. Therefore we looked for common patterns or systematic differences in the factors identified as relevant for different target behaviors by comparing the summaries of the behavioral options grouped in Table S1. However, no systematic differences for the different types of HWTS could be found by comparing the practices in this way (SODIS vs. boiling vs. filtration vs. chlorination). No systematic differences could be observed between factors relevant to any HWTS options compared to switching to safer sources or well testing. However, the predictive value of these comparisons could have been compromised by the small number of cases per behavior. Factors relevant to the hygienic handling of drinking water or well testing were difficult to compare with those for providing safe water via HWTS options or switching to alternative sources, since only a single study was available for each.

For Objective 4, we tried to recognize whether there are any population-specific sets of factors that are important only in certain settings. However, no specific pattern could be identified within the present dataset that would lead to this conclusion. Moreover, differences can be observed between countries and project settings or even within one country for the factors that yielded significant explanatory power for the same safe water consumption behaviors. For example, SODIS usage was determined by a different combination of factors – including some consistent ones – for each of the five different studies that examined this behavior. This is also the case for both projects carried out within Bolivia. Switching to safe water sources was explained by varying psychological determinants both between Ethiopia and Bangladesh and also within Bangladesh, where several studies targeted the collection of drinking water from arsenic-safe options. In summary, it could readily be shown that the pattern of relevant behavioral factors is oftentimes population-specific in this set of studies.

DISCUSSION

A total of 14 studies were included in this multi-country review, all of them based on behavioral theory or a corresponding framework, to assess the determinants for safe water collection, treatment, handling, and storage practices. The behavioral options addressed include such POU HWTS options as SODIS, boiling, filtration, and chlorination. Testing wells for water quality, switching to safe sources, and cleaning of storage vessels were other behaviors studied. All studies assessed behavior using a range of socio-psychological factors as outlined in the RANAS model (Mosler 2012).

The most important result is that the usage of socio-psychological factors in predictive models showed consistently moderate to high explanatory power for the targeted behaviors. This means that surveys including these factors can reliably identify and evaluate the contribution of different motivators for performers and non-performers of safe water practices. The corresponding findings can be used to design behavior change campaigns.

When investigating whether any common behavioral determinants predominantly explain the use of different safe water practices, we found that social norms including the perceived behavior of others, attitudinal factors such as perceived costs and benefits, and feelings towards the behavior as well as knowledge and perceived abilities to perform the behavior were the most important factors

across all studies. This denotes that it is nearly always important for behavior change campaigns to work primarily with these factors. The perception of the behavior of others as well as perceived self-efficacy and action knowledge concerning the desired behavior are very likely to be of interest for behavior change ambitions. The importance of beliefs about costs and benefits of and feelings about the target behaviors varied more strongly, both for different behaviors and between specific settings and populations. However, both should be taken into account when planning a behavior change campaign as they might very likely play a role; they contributed significantly in over half of all cases. Individuals' risk perception of diseases and estimation of the severity of disease played a role in few cases, which is why they may not be addressed predominantly. Nevertheless, we recommend checking in each project for their relevance wherever possible.

With regard to specific factors for the different behavioral options, we found that the factors significant for safe water practices varied both within different practices of HWTS technologies and between other safe water practices.

The same is true for population-specific factors, as the same behavior was determined by different factors when two distinct populations were compared. Different behaviors were determined by different factors even within one country. Therefore, no systematic conclusion can be drawn regarding specific factorial combinations for specific behavioral options or populations, nor for specific settings. These findings stress the unique mindsets of local populations and highlight the importance of a data-driven approach to assessing behavioral drivers in a specific setting. They also underscore the need to develop population-tailored intervention strategies to target safe water consumption behaviors based on evidence acquired prior to their design. Behavioral change techniques for campaign development should be selected on the basis of extensive baseline research that has determined the factors most important to a particular setting in a systematic way.

Further, the findings of this review reflect the fact that only a minority of studies on safe water consumption practices seems to be based on health-psychological theory. In many cases, behavioral determinants are not taken into account at all, not studied explicitly or in a systematic way, or not measured quantitatively, thus not allowing the development of predictive models for behavior. However, such an approach can be very helpful, if not necessary, for the successful development of strategies promoting the uptake and continued usage of behavioral options for safe drinking water consumption. Even more critical, many studies that claim to produce an understanding of behaviors related to safe water consumption or behavioral change do not define the targeted behaviors in a very rigorous way. Different behavioral steps affecting safe water consumption are mixed or are not properly operationalized, thus making it difficult to draw clear conclusions.

Implications for practice

Based on the findings presented here, the entirety of socio-psychological factors that play a role in all health behaviors can be grouped according to their general importance, based on the proportion of cases in which they were found to be relevant in this review.

Existing social norms, knowledge and perception of one's own abilities as well as instrumental and affective attitudinal factors were identified as the most common explanatory psychological determinants for adherence to different behaviors and in different contexts. In detail, this means that the perceived behavior of others is a behavioral determinant which should always be taken into account when designing behavior change strategies.

Further, both how-to-do knowledge and personal confidence in being able to perform a behavior are important determinants for safe water practices that should definitely be considered when designing an intervention program.

Factors from the risk component, vulnerability, severity, and health knowledge played a role in only a minority of cases, and their contribution should be assessed carefully before incorporating them in behavior change strategies.

Factors from the self-regulation block have only been assessed in a less systematic way than the previous ones, so the interpretation of results is more ambiguous and should, therefore, be taken with caution.

Taken together, this means that monetary and non-monetary costs and benefits, consumers' taste preferences, general feelings about performing the behavior, and whether others show the behavior should all be taken

into account in practically every safe water intervention program. Most programs should thus include both persuasive behavior change techniques (BCTs) tackling attitudinal factors and norm BCTs tackling normative factors, as they emerged as relevant in almost all cases, both across a range of behavioral options and across populations and settings (for further information see the fact sheets available online at: http://www.eawag.ch/en/department/ess/empirical-focus/environmental-and-health-psychology-ehpsy/). Programs should further address skills and abilities not only by providing necessary knowledge, e.g., on usage of technology, which can be seen as an elementary step towards a new behavior, but also by fostering people's perceived abilities to use those by drawing back on infrastructure, skills, and ability BCTs.

Other factors such as injunctive and personal norms sometimes do play a role in determining behavior, but more often they showed no significant predictive power in the studies under examination. They should, therefore, only be considered where there is strong evidence that tackling these factors could contribute to behavior change. Risk perceptions, like perceived vulnerability, perceived severity, and health knowledge, seem to be important determinants for targeted behaviors in only few cases. Consequently, these should not be a priority in the design of behavior change programs in general.

These practical conclusions become especially useful for the design of campaigns in situations or project settings in which the range of socio-psychological factors cannot be effectively assessed due to financial, personal, or time constraints, or where this kind of research is simply not feasible. This review can, therefore, serve as a guide for practitioners designing and implementing programs promoting behavior change in the WASH water sector who are limited in their capacity to run comparable research. However, it is evident from this research how the combination of relevant behavioral factors varies greatly, not only between different safe water behavior options but also between different target populations. This means that, despite the general conclusions and recommendations drawn above, a thorough evaluation of the situation, including the socio-psychological characteristics of a specific population regarding a targeted behavior should always be undertaken whenever possible.

Context factors

Some researchers point to the importance of contextual factors for WASH behaviors and criticize their absence in current psychological behavioral theories (Dreibelbis *et al.* 2013). External factors such as infrastructural resources, availability of material and supplies for treatment or proper storage and cleaning utensils for containers can certainly be important preconditions for safe water consumption behavior, as they partially explain the variance in current behaviors. In some of the studies presented here, context factors were included for behavior prediction. Resource availability added additional explanatory power to the models in one SODIS study, where the availability of plastic bottles and firewood showed significant associations with SODIS and boiling, respectively (Tamas *et al.* 2013). Covering the storage container and cleanliness of the container were associated with boiling water for drinking in one study (Sonego *et al.* 2013). Another study on the hygienic handling and storage of drinking water found that the type of container used influenced the probability of it being cleaned (Stocker & Mosler 2015).

However, compared to the sum of socio-psychological factors internal to a person, the external factors identified in some of the studies explained only a minor part of the variance in behavioral differences between those performing target behaviors or using technologies and others who do not. The inclusion of these contextual factors did not lead to any major increase in the explanatory power of the models. It could thus be argued that most external factors, such as environmental or technological conditions, are also subsumed within psychological factors, so their inclusion does not necessarily increase the explanatory power of the models. For example, a long walking distance to a source would be represented by high perceived efforts (instrumental belief), which again is included as a psychological variable among the attitudinal factors. The availability of materials, such as bottles for SODIS or chlorine for treatment, would be represented in the perceived ability to perform a target behavior.

Strengths and limitations

One strength of this review is its rigorous comparison of quantitatively measured socio-psychological factors used as

determinants for the prediction of safe water behaviors. All the studies included not only measured behavioral determinants quantitatively but also correlated them with the level of target behavior on the basis of statistical models. In contrast to studies relying merely on qualitative data, our study allows conclusions to be drawn about the predictive power of individual determinants to explain behavioral variances. The systematic listing of these determinants makes their importance directly comparable and gives the relative frequency of significant contributions to the explanation of behavioral variances.

Moreover, the heterogeneous picture of factors that emerged as significant predictors for behavioral options indicates how much variation exists, not only between different behaviors but also between diverse settings and populations. To our knowledge, no other work has been carried out using a similar approach in this field.

However, one potential limitation to this systematic comparison is that, despite the common health-psychological theory underlying the models, the survey questions had to be adapted to the local sociocultural context in each study. Some constructs were thus operationalized in a slightly different way, a fact which should also be taken into account when interpreting the data (for a detailed look at the operationalization details, please refer to Table S2).

CONCLUSION

To date, only a small proportion of intervention studies seem to have used a systematic approach based on health-psychological theoretical models to assess behavioral factors and thus explain safe water consumption practices. This review combined and compared results on socio-psychological factors for several safe water consumption behaviors from 14 studies in several countries. Across all kinds of behaviors and contexts, the socio-psychological factors examined explain the targeted behaviors to a great extent. This means that including these factors in the behavioral analysis allows us to understand behaviors very well, thus providing an instrument to design effective behavior change campaigns. In particular, social norms, especially other people's behavior, was found to be of importance with very high recurrence for all the safe water behaviors examined. Action knowledge and self-efficacy convictions were also predictive in the majority of studies. Instrumental and affective beliefs were important in over half of all cases but not in others. Risk perception and health knowledge contributed significant explicatory power in only a few cases. Further, the combination of factors that was important in explaining targeted behaviors varied and was not specific for any of the safe water behaviors or populations studied.

Taken together, these findings highlight the importance of a population-tailored approach in the development of intervention strategies promoting behavior change in safe water consumption practices. To meet the characteristics of the specific target population and setting, programs should be designed in a data-driven way. Wherever no such approach is feasible, this review can serve as a rough guide for practitioners working on intervention campaigns, which should take into account the factors that have been shown to be important in this work.

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REFERENCES

Abraham, C. & Michie, S. 2008 A taxonomy of behavior change techniques used in interventions. *Health Psychology* **27** (3), 379–387.

Arnold, B. F. & Colford, J. M. 2007 Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhea in developing countries: a systematic review and meta-analysis. *The American Journal of Tropical Medicine and Hygiene* **76** (2), 354–364.

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T. & Bartram, J. 2014 Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. *PLoS Medicine* **11** (5), e1001644.

Bartholomew, L. K. & Mullen, P. D. 2011 Five roles for using theory and evidence in the design and testing of behavior change interventions. *Journal of Public Health Dentistry* **71**, S20–S33.

Brown, J. & Clasen, T. 2012 High adherence is necessary to realize health gains from water quality interventions. *PLoS One* **7** (5), e36735.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C. & Schmidt, W. P. 2010 Water, sanitation and hygiene for the prevention of diarrhoea. *International Journal of Epidemiology* **39** (Suppl. 1), i193–i205.

Chu, W., Li, D., Gao, N., Templeton, M. R., Tan, C. & Gao, Y. 2015 The control of emerging haloacetamide DBP precursors with UV/persulfate treatment. *Water Research* **72**, 340–348.

Clasen, T. 2015 Household water treatment and safe storage to prevent diarrheal disease in developing countries. *Current Environmental Health Reports* **2** (1), 69–74.

Clasen, T., Schmidt, W.-P., Rabie, T., Roberts, I. & Cairncross, S. 2007 Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. *BMJ: British Medical Journal* **334** (7597), 782–791.

Dreibelbis, R., Winch, P. J., Leontsini, E., Hulland, K. R., Ram, P. K., Unicomb, L. & Luby, S. P. 2013 The Integrated Behavioural Model for Water, Sanitation, and Hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. *BMC Public Health* **13** (1), 1015.

Enger, K. S., Nelson, K. L., Rose, J. B. & Eisenberg, J. N. 2013 The joint effects of efficacy and compliance: a study of household water treatment effectiveness against childhood diarrhea. *Water Research* **47** (3), 1181–1190.

Fishbein, M. & Ajzen, I. 2010 *Predicting and Changing Behavior: The Reasoned Action Approach*. Psychology Press (Taylor & Francis), New York, NY, USA.

Floyd, D. L., Prentice-Dunn, S. & Rogers, R. W. 2000 A meta-analysis of research on protection motivation theory. *Journal of Applied Social Psychology* **30** (2), 407–429.

Hulland, K. R., Martin, N., Dreibelbis, R., Valliant DeBruicker, J. & Winch, P. 2015 *What Factors Affect Sustained Adoption of Safe Water, Hygiene and Sanitation Technologies? A Systematic Review of Literature*. EPPI-Centre, Social Science Research Unit, UCL Institute of Education, University College London, London, UK.

Luilo, G. B. & Cabaniss, S. E. 2011 Predicting total organic halide formation from drinking water chlorination using quantitative structure-property relationships. *SAR and QSAR in Environmental Research* **22** (7–8), 667–680.

McLennan, J. D. 2000 To boil or not: drinking water for children in a periurban barrio. *Social Science & Medicine* **51** (8), 1211–1220.

Michie, S., Johnston, M., Francis, J., Hardeman, W. & Eccles, M. 2008 From theory to intervention: mapping theoretically derived behavioural determinants to behaviour change techniques. *Applied Psychology* **57** (4), 660–680.

Mintz, E. D., Reiff, F. M. & Tauxe, R. V. 1995 Safe water treatment and storage in the home: a practical new strategy to prevent waterborne disease. *JAMA-Journal of the American Medical Association-US Edition* **273** (12), 948–953.

Moser, S. & Mosler, H.-J. 2008 Differences in influence patterns between groups predicting the adoption of a solar disinfection technology for drinking water in Bolivia. *Social Science & Medicine* **67** (4), 497–504.

Mosler, H.-J. 2012 A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. *International Journal of Environmental Health Research* **22** (5), 431–449.

Ngai, T. K. K., Shrestha, R. R., Dangol, B., Maharjan, M. & Murcott, S. E. 2007 Design for sustainable development–Household drinking water filter for arsenic and pathogen treatment in Nepal. *Journal of Environmental Science and Health, Part A* **42** (12), 1879–1888.

Parker Fiebelkorn, A., Person, B., Quick, R. E., Vindigni, S. M., Jhung, M., Bowen, A. & Riley, P. L. 2012 Systematic review of behavior change research on point-of-use water treatment interventions in countries categorized as low- to medium-development on the human development index. *Social Science & Medicine* **75** (4), 622–633.

Prüss-Ustün, A., Bartram, J., Clasen, T., Colford, J. M., Cumming, O., Curtis, V. & Cairncross, S. 2014 Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Tropical Medicine & International Health* **19** (8), 894–905.

Rainey, R. C. & Harding, A. K. 2005 Acceptability of solar disinfection of drinking water treatment in Kathmandu Valley, Nepal. *International Journal of Environmental Health Research* **15** (5), 361–372.

Rosenstock, I. M. 1974 Historical origins of the health belief model. *Health Education & Behavior* **2** (4), 328–335.

Rufener, S., Mausezahl, D., Mosler, H.-J. & Weingartner, R. 2010 Quality of drinking-water at source and point-of-consumption–drinking cup as a high potential recontamination risk: a field study in Bolivia. *Journal of Health, Population, and Nutrition* **28** (1), 34–41.

Schwarzer, R. 2008 Modeling health behavior change: how to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology* **57** (1), 1–29.

Smith, E. M., Plewa, M. J., Lindell, C. L., Richardson, S. D. & Mitch, W. A. 2010 Comparison of byproduct formation in waters treated with chlorine and iodine: relevance to point-of-use treatment. *Environmental Science & Technology* **44** (22), 8446–8452.

Sonego, I. L. & Mosler, H.-J. 2013 *Rapport sur l'Enquête de Référence sur le Comportement lié à l'Eau; Hygiène et Assainissement familial au Burundi*. [Baseline report on Water, Hygiene, and Sanitation Practices in Burundi families] Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland. Retrieved

from: http://www.eawag.ch/fileadmin/user_upload/tx_userprofiles/upload/sonegoin/burundi_working_paper_2013.pdf.

Sonego, I. L., Huber, A. C. & Mosler, H.-J. 2013 Does the implementation of hardware need software? A longitudinal study on fluoride-removal filter use in Ethiopia. *Environmental Science & Technology* **47** (22), 12661–12668.

Stocker, A. & Mosler, H.-J. 2015 Contextual and sociopsychological factors in predicting habitual cleaning of water storage containers in rural Benin. *Water Resources Research* **51** (4), 2000–2008.

Tamas, A., Meyer, J. & Mosler, H.-J. 2013 Predictors of treated and untreated water consumption in rural Bolivia. *Journal of Applied Social Psychology* **43** (7), 1394–1407.

Tobias, R. 2009 Changing behavior by memory aids: a social psychological model of prospective memory and habit development tested with dynamic field data. *Psychological Review* **116** (2), 408–438.

van Geen, A., Ahsan, H., Horneman, A. H., Dhar, R. K., Zheng, Y., Hussain, I., Ahmed, K. M., Gelman, A., Stute, M., Simpson, H. J., Wallace, S., Small, C., Parvez, F., Slavkovich, V., Loiacono, N. J., Becker, M., Cheng, Z., Momotaj, H., Shahnewaz, M., Seddique, A. A. & Graziano, J. H. 2002 Promotion of well-switching to mitigate the current arsenic crisis in Bangladesh. *Bulletin of the World Health Organization* **80** (9), 732–737.

Wheeler, J. & Agha, S. 2013 Use of Certeza point-of-use water treatment product in Mozambique. *Journal of Water, Sanitation and Hygiene for Development* **3** (3), 341–348.

Wolf, J., Prüss-Ustün, A., Cumming, O., Bartram, J., Bonjour, S., Cairncross, S., Clasen, T., Colford Jr, J. M., Curtis, V., De France, J., Fewtrell, L., Freeman, M. C., Gordon, B., Hunter, P. R., Jeandron, A., Johnston, R. B., Mäusezahl, D., Mathers, C., Neira, M. & Higgins, J. P. T. 2014 Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: systematic review and meta-regression. *Tropical Medicine & International Health* **19** (8), 928–942.

World Bank Group 2015 *World Development Report 2015: Mind, Society, and Behavior*. World Bank, Washington, DC. Retrieved from: https://openknowledge.worldbank.org/handle/10986/20597.

Wright, J., Gundry, S. & Conroy, R. 2004 Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine & International Health* **9** (1), 106–117.

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