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Behavioural determinants of using fluoride removal filters in rural Ethiopia

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The occurrence of high fluoride concentration in ground - and surface water of the Ethiopian Rift Valley leads to the risk of developing dental and skeletal fluorosis. Bone char filtration is a simple, efficient and low cost technology to remove fluoride out of drinking water. In six project areas in the Ethiopian Rift Valley, fluoride removal household filters on the basis of bone char material have been implemented. This study examines possible predictors of consuming filtered water derived from various behavior change theories. In a complete survey, all filter beneficiaries were interviewed through structured face-to-face interviews. Logistic regressions were carried out to reveal factors predicting the filter use. The results show that the consumption of only filtered water is mainly related to normative beliefs concerning guests and perceived behavioral control in terms of filter capacity. Based on the results, possible intervention practices are discussed.

Introduction

The occurrence of high fluoride concentration in ground and surface water has caused a serious public health problem in Ethiopia, especially in the Ethiopian Rift Valley (Kloos & Tekle-Haimanot, 1999; Tekle-Haimanot, Melaku, Kloos, Reimann, Fantaye, Zerihun & Bjorvatn, 2006; Tekle-Haimanot, 2005).

Fluoride is mostly absorbed into the human body by drinking or cooking with water containing fluoride. An excess fluoride intake can cause dental and skeletal fluorosis. Symptoms range from irregular brown patches on teeth, deformation of bones, limitation of joint movements and even crippling (crippling fluorosis) in the last stage of the disease, accompanied by serious psychosocial impacts (Tekle-Haimanot, 2005).

Out of a 10 million population in the Ethiopian Rift Valley, 8.5 Million people are exposed to high fluoride contamination (Tekle-Haimanot, 2005). Medical treatment of the disease has been found difficult and mostly ineffective. Therefore, the prevention of high fluoride consumption becomes crucial.

Bone char filtration is an efficient, simple and low-cost defluoridation technique, applicable at household and community level in semiarid rural areas lacking alternative water sources like rainwater harvesting or piped water supplies (Kloos & Tekle-Haimanot, 1999; Tekle-Haimanot, 2005). Even though considerable achievements have been made in fluoride mitigation since the problem's detection in urban areas, fluoride is still not removed effectively (Malde, 2003). In rural areas, the case is even worse, since only few filter systems are installed, but are not sustained, mostly due to lack of support and maintenance (Tekle-Haimanot, 2005). Besides the research on medical consequences of fluoride (e.g.Malde, 2003; Wondwossen, 2006), little research has been done so far on the topic of continuous filter use. As a result, different social, situational and psychological determinants and consequences of filter use remained unclear.

The aim of the present study is to address this research gap by investigating evidence-based enhancing and hindering factors of people's acceptance and use of a fluoride removal filter. A clearer understanding of these factors enables planning of behavior change interventions in order to promote habitual use of the new technology.

Deriving behavioural determinants

For inferring the determinants of filter use we rely on the Theory of Planned Behavior (Fishbein & Ajzen, 2010), the Health Action Process Approach (Schwarzer, 2008), and research on habit development (Tobias, 2009). We postulate that for the formation of habitual behavior, five blocks of factors have to be positive with regard to the new behavior: risk perception, attitudinal beliefs, normative beliefs, ability beliefs, and maintenance beliefs. First, the formation of risk perception is the result of a comprehension process triggered with information interventions which means that with the given information the person is able to form an understanding of the menacing health risk. The risk beliefs to be formed are perceived vulnerability and perceived severity. Perceived vulnerability refers to a person's subjective perception of his or her risk of contracting a particular condition or illness. Perceived severity is a person's perception of the seriousness of the consequences of contracting a particular condition or illness. Second, the formation of positive attitudinal beliefs is the result of persuasion processes induced by persuasive interventions. Resulting from these processes are instrumental beliefs like those about costs and benefits of the new. From the third process, the social influence process, a positive descriptive and injunctive norm should be the outcome of normative interventions. The descriptive norm expresses perceptions of which behaviors are typically performed and the injunctive norm perceptions of which behaviors are typically approved or disapproved. According to Cialdini (2003) normative interventions have to be in the way that injunctive normative messages about a strongly disapproved behavior are effective but descriptive normative messages that a undesired behavior is regrettably frequent is counter effective. In the fourth process, the control process, ability interventions help people to get confidence in their ability beliefs which means they get a better appraisal of what they think they can do. One outcome should be a positive self-efficacy and perceived behavioural control which is the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations (Bandura, 2004). Finally, in the fifth process, self-regulation processes are happening which means that the person is managing conflicting goals and distracting cues when intending to implement a behavior. Planning interventions as implementation intentions help to translate goals into actions by preventing to become distracted, avoid to fall back into bad habits, or inhibit failing to get started (Gollwitzer & Sheeran, 2006). Factors playing a decisive role for maintaining the behavior are commitment to the behavior, remembering the behavior, as well as perceiving the behavior as an automated habit.

Method

The present field study is part of the fluoride mitigation project „Optimization and acceptance of fluoride removal options for drinking water in rural Ethiopia". It is a collaboration project of Eawag (Swiss Federal Institute of Aquatic Science and Technology), the University of Addis Ababa, the Swiss NGO HEKS (Hilfswerk der Evangelischen Kirchen Schweiz), the Ethiopian NGO OSHO (Oromo Self Help Organization) and the Kenyan NGO CDN (Catholic Diocese of Nakuru). A pilot project started in September 2007 with the distribution of 121 household filters. In April 2010, the project was continued with the implementation of another 200 filters.

Study areas

Six different villages had been selected by the NGOs and the research team based on fluoride concentration levels, accessibility and the permission of political and regional leaders. All of the project areas are located in the northern part of the Ethiopian Rift Valley. Despite an elevation around 1650 m the temperature is quite hot (16 - 30 °C) with local intermittent rain showers from February to March and a main rainy season from mid-June to mid-September (Tekle-Haimanot, 2005).

The project areas are rural villages with low-income families. People live basically in little houses built by wood, earth, tin, cement or concrete. Most of the people are self-sustaining farmers and their infrastructure is quite simple. They neither have electricity nor sanitation nor running water in the households. Usually, people go fetching water with jerry cans at a public water source like a borehole. Some people also hold private hand dug wells or fetch lake water as well as collect rain water during the rainy season. The fluoride content in the boreholes of the project areas is accounted for 2 mg/l up to 18 mg/l, Lake Awassa contains a fluoride level of 7.5 mg/l, and the fluoride content in Lake Ziway is between 2 and 4 mg/l. These fluoride levels partially exceed drastically the WHO guideline value of 1.5 mg/liter.

Design

The study design was a complete survey of all filter beneficiaries in the project areas. Filter beneficiaries of the pilot project were interviewed in December 2009 (n = 115). One filter beneficiary in the pilot survey refused participation. Five beneficiaries could not be interviewed because of filter loss, emigration or absence during the interviewing period. Filter beneficiaries who had received a filter in April 2010, were interviewed approximately one week after implementation for the baseline survey (n = 160). In the baseline survey all filter beneficiaries consented to give the interview.

Procedure

Because of high illiteracy, the data collection was carried out through structured interviews by a team of ten local college students. Before each survey the interviewer team was introduced into bone char technology and trained in conducting the interviews in a workshop during two days. Moreover, the team was supervised during the investigation. The households were visited without preannouncement, but beneficiaries from the baseline survey agreed being part of the study when receiving a filter. The local field manger and the community facilitators from the villages helped the interviewers to find the households with filters. If possible, the interviews were held with persons responsible for drinking water in the respective household.

The questionnaires were translated by the local field manager of Eawag and the social worker of OSHO from English into Amharic and Oromifa and revised by the interviewers during the workshop. The applicability of the pilot questionnaire was verified in a pretest while conducting the preliminary interviews and thus revised. The questionnaires were designed to cover various factors of interest underlying the filter use and the consumption of filtered water, including qualitative and quantitative variables. Qualitative variables were categorized and assigned by two independent experts; inter-rater reliability was calculated with the Cohen's Kappa (K). In general, the quantitative bipolar variables were measured on a 9-point Likert-scale, for unipolar variables a 5-point Likert-scale was used. After data collection, principal factor analysis with varimax rotation and reliability analysis (Cronbach's alpha (α)) were executed with SPSS 17.

The preliminary as well as the baseline questionnaire included items concerning the *overall attitude* (e.g. Tamas, 2009), *return* (e.g. Tobias, Brügger & Mosler, 2009) *health impact* (e.g. Tamas, 2009), perceived *taste* (e.g. Tamas, 2009) and *color* of filtered water as well as beliefs concerning *costs*. The *injunctive* and *subjective norm* was covered following Park & Smith (2007) and Armitage (2005). Further items were applied to the reaction of guests. *Self-efficacy* was measured referring to Armitage & Conner (1999) and Armitage (2005), *perceived behavior control* was assessed in terms of having enough filtered water available for consumption. Furthermore, risk perception was covered by the perceived *vulnerability* and perceived *severity* of dental and skeletal fluorosis (e.g. Orbell, Lidierth, Geeraert, Uller, Uskul & Kyriakaki, 2009). *Commitment* of filter use was assessed following Tamas (2009), *habit* of filter use comprised items according to Orbell et al. (2001).

The *dependent variable* for the current consumption of filtered water was quantified in terms of the percentage of drinking filtered water and cooking with filtered water. Participants were asked to show the interviewer a regular cup and to assess how many of these cups the entire family drinks per day. With the interviewer's estimation of the content of the cup, the total litres consumed per day could be calculated. Afterwards people were asked how many cups they drink from the filter and how many cups they drink from another water source. The calculated percent of cooking with filtered water followed the same procedure. In addition, participants were asked how many times a day they filled the filter with water. From this question a total of filtered water per day was calculated.

Results

Out of the total sample ($N = 275$), 63.6% of the beneficiaries stated to use only filtered water for drinking and cooking. From those who variably consume filtered water, 9.8% indicated to cover half, and 7.3% indicated to cover three quarters of their water consumption with filtered water. On average, filter owners consume 86.3% filtered water of their total water consumption. All of the filter beneficiaries use filtered water for drinking; 86.5% of the beneficiaries stated to drink exclusively filtered water, the minimal amount of drinking filtered water was 12.5%. Nothing but filtered water for cooking is used by 67.2% of the beneficiaries, 8.4% of the people use filtered water in equal share with unfiltered water and 10.9% of the beneficiaries do not cook with filtered water at all. On average, filtered water is used in 94.3% for drinking and in 78.7% for cooking.

The filter is filled between once and eight times a day. The mean range is 2.68 (SD = 1.15, N = 274) for the total sample. Filling the filter correlates positively with the number of people per household ($r = .284$, $p < .001$).

Factors predicting filter use

In consequence of the frequencies of consumption of filtered water, for further analysis the beneficiaries were divided into two groups: beneficiaries who already use only filtered water for drinking and cooking versus people who still use additionally untreated water. To evaluate the main factors that predict behavior, a binary logistic regression was calculated. The logistic regression reveals which factors differentiate between persons who consume only filtered water and persons who consume filtered and raw water. The results are displayed in Table 1. A positive B-value in table 1 means that the higher this factor the more likely it is that a person consumes only filtered water and a negative B-values implies that that the lower this factor the more likely it is that a person consumes raw water and filtered water. Only significant factors have to be taken into account meaning that the p-value in table on has to be lower or equal than .05.

The examination of the parameter estimates revealed that two of the investigated normative beliefs such as the *importance to offer filtered water to guests* and the *feeling of pride to present filtered water to guests* were positively significant. A significant regression coefficient resulted furthermore from the *filter capacity*, reflecting the sufficient availability of filtered water to consume. In addition, *taste* showed a positive significant impact (compare Table 1). *Self-efficacy*, factors of *risk perception* as well as *health knowledge*, *commitment* and *habit* variables did not contribute significantly to the regression.

In total, there was an acceptable model fit (see Table 1), whereby 81.5% of users were correctly classified. The *VIF* values indicated that correlations within the independent variables were acceptable. A residual analysis showed a normal distribution of standardized residuals. Only 2.95% of all cases were found above the 95% level. Cooks distance statistics showed no influential cases in the regression. Moreover, there is no evidence for heteroscedasticity.

Discussion

The purpose of the present research was to reveal substantial behavioural determinants of using fluoride removal household filters. Concerning filter use, it was hypothesized that positive *attitudinal* and *normative beliefs*, *perceived behavior control* and *self-efficacy* as well as *commitment* and *habit* of filter use, increases the probability of consuming exclusively filtered water. Most notably, the analysis of these predictors reveals the influence of social norms referring to guests, *perceived behavior control* and perceived *taste* of filtered water on filter use.

Specific normative beliefs in relation to guests such as the individual *importance to offer filtered water to guests* and the *feeling of pride to present filtered water to guest* demonstrate the importance of social contacts and social status in the Ethiopian culture. The more important it is for beneficiaries and the prouder they are to present filtered water to guests, the more likely they consume exclusively filtered water. These findings confirm the hypothesized impact. Due to the fact that having visitors is culturally very common in Ethiopia, to offer filtered water may imply a higher social status.

Perceived behavior control in the context of fluoride removal filters usage is understood as having enough filtered water available to consume for the whole family in terms of filter capacity. The positive impact indicates that the more people feel that they have enough filtered water available respectively the more they produce filtered water, the more it is probable that they consume only filtered water. This finding coincides with the hypothesized effect. In average, families have 6.5 family members, so a lot of water has to be filtered to cover the water demand of each family member. The result suggests that beneficiaries consume filtered water but for this purpose they need to filter enough. In this respect, the perceived size of the filter bucket is important. People would consume more filtered water if they had a bigger bucket, which has to be filled once or twice per day instead of filling a smaller filter several times per day to cover the water demand of the entire family.

The positive impact of perceived *taste* indicates that the better the taste of filtered water is perceived, the more probable it is that users consume only filtered water. This result confirms the hypothesized impact and previous findings from studies on solar water disinfection (SODIS), in which the predictive power of perceived taste on SODIS use (Heri & Mosler, 2008) and the intention to consume SODIS treated water (Heri & Mosler, 2008; Tamas, 2009) has been noticed. Overall, taste of filtered water was rated as very good. This might be related to the cool temperature and the less turbid water coming from the filter.

Further *attitudinal beliefs*, *self-efficacy*, perceived *severity* of contracting dental and skeletal fluorosis, *commitment* to use the filter as well as *habit* variables do not seem to have any predictive power function as hypothesized. Even though in recent SODIS studies the *overall attitude* proved to be a decisive predictor of consumption of treated water (Altherr, Mosler, Tobias & Butera, 2008).

Table 1. Logistic regression analysis for variables predicting filter use

Variable		*B*	*SE B*	Exp (*β*)	*p*
Risk perception	Vulnerability	-.270	.298	.764	.366
	Severity dental fluorosis	.991	1.13	2.69	.383
	Severity skeletal fluorosis	.719	1.72	2.05	.676
Attitudinal beliefs	Attitude	-1.714	1.78	.180	.335
	Return	-1.154	1.87	.315	.537
	Health impact	2.640	1.63	14.01	.105
	Color	-.012	.853	.988	.988
	Taste	**2.003**	**.949**	**7.41**	**.035**
	Costs	-.115	.308	.892	.710
Normative beliefs	Injunctive norm	.362	.336	1.43	.281
	Subjective norm	-.521	.665	.594	.434
	Importance guests	**1.467**	**.496**	**4.34**	**.003**
	What guests think	.480	.251	1.62	.056
	Ashamed/proud guests	**4.771**	**1.05**	**118.02**	**.000**
Ability beliefs	**PBC (filter capacity)**	**2.963**	**.571**	**19.35**	**.000**
	Self-efficacy	.596	1.17	1.81	.612
Self regulation	Commitment	1.856	1.22	6.39	.128
	Perceived habit	1.536	1.51	4.64	.308
	Automaticity	.271	.244	1.31	.268
	Remembering	.581	.821	1.78	.479
Constant		-10.920	2.61	.000	.000

Note. Nagelkerkes R^2 = .550, LR-χ^2 = 138.956 with *df* = 20 (p < .000), *N* = 271 (due to missing listwise). A forced entry method was used for the calculation. Because of different measurement, health knowledge is not considered in the analysis.

Limitations of the study and future research

There are some limitations of the present study which are noteworthy. One limitation is the self-reported data and the interrogation through interviewers that always may evoke a social bias. During the workshop, the interviewers were sensitized to that problem and the importance of the introduction part before starting the interview. In the introduction part the interviewers pointed out that participants should answer in their interest as honestly as possible. However, another type of survey like a paper pencil investigation would have been impossible due to high illiteracy rate in the population and an observed behavior monitoring would have been too expensive.

Further, the behavior measurement is in need of improvement. It seems appropriate in future research to focus on how much water is filtered per day as dependent variable, because it is assumed that water, which has been filtered, will be consumed by the family members. On the one hand, with this variable it would be possible to calculate linear instead of logistic regressions with the advantage that the results will be more conclusive and more meaningful to interpret. On the other hand, it is supposed that beneficiaries sometimes still consume unfiltered water. A more exact indication regarding how much water beneficiaries filter per day by a calculation of additional items such as when people fill the filter (e.g. if it is empty or half empty) would be insightful. In addition, tally counters and water level recorders have been recently implemented whereby self-reported data can be verified. However, various studies about health behavior implementing self-reported data indicate its significance for behavior performance.

Implications for practice and conclusion

Bone char filtration seems to be widely accepted within the household filter beneficiaries, even though most of them know that the filter material is a processed animal product. This defluoridation technique which is simple, effective, inexpensive seems to be socially accepted by the Ethiopian population. In addition to research concerning fluoride distribution and fluoride removal techniques, the social psychological investigation of the bone char technology in the context of filter use provides a fundamental contribution to project specific implementation approaches. With knowledge about decisive determinants of filter use, specific intervention strategies can be designed to enhance the habitual behavior through influencing psychological and situational factors.

When implementing household filters, the advantage of bigger buckets with more storage capacity should be considered due to the result that the probability to consume only filtered water increases if people feel that there is enough water available from the filter.

It is recommended to induce new beneficiaries to fill the filter more than once or twice a day depending on the number of persons per household by giving them rules of thumb (e.g. filling the filter once per day per person in household). Prompts or a daily routine planning together with promoters could be effective intervention strategies to form a habit in terms of an automatic behavior performance of filling the filter to have as much water as needed for the entire household.

Prompts are external memory aids which point out to an individual to execute a certain behavior in a specific moment (Mosler & Tobias, 2007) and have been proven to be efficient memory aids in promotion campaigns (e.g. De Young, 1993; Tobias, 2009). Furthermore, it is supposed that prompts act as situational cue stimuli which lead to habit formation if they are constantly activated (Dahlstrand & Biel, 1997; Aarts et al., 1998). Effective tools for daily routine planning are for example implementation intentions. Implementation intentions help people to perform a specific behavior by making concrete plans of actions that specify *how*, *where* and *when* actions should be performed to achieve an intended goal. Implementation intention supporting techniques are for example formalized verbal intention sentences like „in situation X I will do Y“(Gollwitzer, 1999), which could be developed together with filter users. In this context, it should be discussed with the users *when* the filter is to be filled to fit their daily routines. At the same time it should be discussed *how* to incorporate the consumption of filtered water in their daily activities. Since people are most of the day in the fields, it would be appropriate to make plans how they can take filtered water with them.

Intervention strategies to maintain or improve filter use should target the social norm related to guests. To make the social status more salient respectively to enhance the importance to present filtered water to guests, public commitment is a useful intervention strategy. Individuals communicate in public to perform a certain behavior (Mosler & Tobias, 2007). The public commitment is created with a descriptive norm for other people and at the same time it evokes a social pressure to do what they communicated in public for themselves (Tamas, 2009). This intervention technique has been proved to be effective in various studies (e.g. Dwyer, Leeming, Cobern, Porter & Jackson, 1993; De Young, 1993).

Despite some limitations, the study reveals the project's progresses. A lot of interesting findings became evident which have already been implemented within the project to enhance filter use. Future results will reveal the usefulness and practicability of the approach. Nevertheless, the study adduced evidence that the acceptance, adoption and use of technical innovations by users can be well explained with psychological research.

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