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SPECIAL ISSUE: ADVANCING SOCIO-HYDROLOGY

The effect of socio-economic characteristics on the use of household water treatment via psychosocial factors: a mediation analysis

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ABSTRACT

Household water treatment (HWT) can tackle the issue of consuming unsafe drinking water at home. While household socio-economic characteristics are often assumed to influence the psychology of HWT use, no study has rigorously tested such an assumption. We aim to fill the gap by a cross-sectional study in a rural area in Sumba Timur, Indonesia (N = 256). Using mediation analysis, we demonstrated that psychosocial factors mediated the relationship between socio-economic characteristics and the use of household water treatment, and socio-economic characteristics strongly influenced the psychology of household water treatment usage. The use of HWT asked from different angles allowed more degrees of freedom to better assess the true status of the HWT usage, via the principal component of the answers. This paper concludes that "causal" relationship pathway from socio-economic characteristics to the use of HWT via psychosocial factors is a realistic assumption when assessing the influence of socio-economic characteristics on HWT.

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Introduction

The United Nations Sustainable Development Goals aim "*by 2030*, [to] *achieve universal and equitable access to safe and affordable drinking water for all*" (WWAP/UN-Water 2018). This aim means that every house has a connection to sufficient and 24-h available water supply, inexpensive, and free from major water contamination. Even though the progress looks promising, the latest report by World Health Organization (WHO) and United Nations Children's Fund (UNICEF) (2017) mentions that 2.1 billion people (29% of the global population) still are not connected to such an access. Bain *et al.* (2014) have estimated that 1.8 billion people have only access to faecally contaminated water sources.

Household water treatment (HWT) is one of the methods to improve water quality at household level, e.g. by boiling, water filtration, or chlorination. HWT is especially helpful if the water source is contaminated (Sobsey *et al.* 2008). Studies have found that if one practices HWT correctly and regularly, it can reduce the risk of water-related diseases, such as diarrhoea (Brown and Clasen 2012, Wolf *et al.* 2018). However, many households still do not practice HWT regularly. This puts these households at risk of contracting water-borne diseases because they still drink untreated water that could otherwise have been treated with ease at home (Hunter *et al.* 2009). Thus, there is a need to understand why people still do not use HWT, while its health benefits are clear.

Previous studies have found that socio-economic characteristics are strongly associated with the use of HWT. Wealthier households with higher education level were more likely to treat water in Bhutan (Rahut *et al.* 2015), Cameroon (Fotue Totouom *et al.* 2012) and India (Dasgupta 2004). Other associations are with perception that untreated water is safe (Williams *et al.* 2015), no social pressure from community (i.e. norm) to use HWT (Lilje *et al.* 2015), or negative feelings toward treated water due to its taste (Orgill *et al.* 2013). The latter examples are often described as psychosocial factors or behavioural determinants, which are defined as one's thoughts and feelings that influence behaviour (Macleod and Davey Smith 2003).

A system-level approach to explain the use of HWT is therefore needed, which combines socio-economic characteristics and psychosocial factors (Dreibelbis and Winch 2013, Daniel *et al.* 2018). Seimetz *et al.* (2016) and Stocker and Mosler (2015) have combined socio-economic characteristics and psychosocial factors in their analysis using multivariate linear regression, treating both elements at the "the same level." A new approach has been proposed by Daniel *et al.* (Daniel *et al.* 2019), using Bayesian belief network (BBN) that depicts a causal relationship between variables. The authors modelled a "causal" relationship wherein socio-economic characteristics influenced the use of HWT through psychosocial factors, i.e. via indirect pathways, as also partly suggested by RANAS (Risk, Attitude, Norms, Ability, and Self-regulation) psychological theory. RANAS theory suggests both direct and indirect pathways between socio-economic characteristics and output behaviour (Mosler 2012, Contzen and Mosler 2015), even though other studies outside water, sanitation, and hygiene (WASH) have found evidence only for indirect pathways (Gecková *et al.* 2005, Wells and Harris 2007, Rodriguez *et al.* 2014, Martinez *et al.* 2018).

To our knowledge, there is no study from the WASH field investigating potential "causal" pathways connecting socio-economic characteristics, psychosocial factors and WASH related behaviour. Therefore, the objective of this paper is to start filling this gap. We hypothesize that the household's socio-economic characteristics (SEC) are mediated by psychosocial factors that

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Supplemental data for this article can be accessed here.

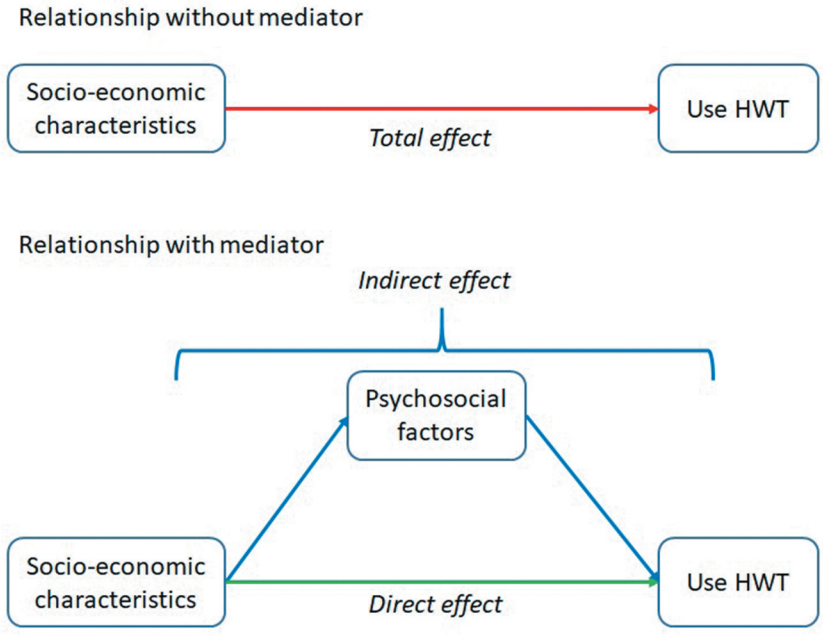

Figure 1. Hypothetical pathways of the mediation analysis: direct effect of socio-economic characteristics on the use of HWT (green arrow) or indirect effect via psychosocial factors (blue arrow).

influence the behaviour of using HWT (Fig. 1). Moreover, we hypothesize that better socio-economic characteristics of respondents generate more favourable psychosocial conditions, that result in higher chance of using HWT.

We used data from a cross-sectional study of a rural area on Sumba island, Indonesia, and analysed them using mediation analysis. Sumba is one of the poorest locations in Indonesia with high frequency of open defecation and limited access to clean water (Sungkar *et al.* 2015). Mediation analysis (sometimes called path analysis) is intended for understanding the relationship between two variables via inclusion of a third variable, called the mediator variable (Mackinnon *et al.* 2007). In this article, mediation analysis was used to understand the mechanisms of how socio-economic characteristics influence the use of HWT, whether socio-economic characteristics directly influence the use of HWT or this influence is mediated by mediator variables called RANAS psychosocial factors.

Materials and methods

Ethics statement

The study setting, including the questionnaire, were approved by the Human Research Ethics Committee of Delft University of Technology and was authorised by the Agency for Promotion, Investment and One-Stop Licensing Service at the province (East Nusa Tenggara) and district (East Sumba) level. Participation was voluntary and written informed consent was obtained from all respondents. Informed consent was also obtained from the village head before the field survey.

Study setting

A cross-sectional study was undertaken in August 2018 in nine villages in the district of Sumba Timur, Province Nusa Tenggara Timur, Indonesia (Fig. 2). We initially targeted a sample size based on the methodology of (Krejcie and Morgan 1970, Wilson Van Voorhis and Morgan 2007) (see Supplementary material for more information). In total, 377 households were randomly selected during transect walk within each village. The questionnaires were developed in English and translated into Bahasa Indonesia by the first author. Six local people who are familiar with the location were hired to conduct the interviews. Training and pilot tests were conducted before the survey.

A structured household interview was in the Open Data Kit (ODK) platform on smartphone (https://opendatakit.org/) and its content, especially the psychosocial-related questions (Table 1), was inspired by RANAS theory (Contzen and Mosler 2015). The questionnaire covered household's socio-economic characteristics, WASH knowledge and perception, health status, WASH-related behaviour, e.g. HWT use, hand washing, sanitation, and ended with structured observations. Most of the psychosocial-related questions were measured by a five-item Likert scale as described later, while the socio-economic variables were categorical. The target respondents, where possible, were mothers who were primary caregivers in the households. In case of mother was not available at that time, we interviewed the father or the oldest person in that house.

Variables of the mediation analysis

Socio-economic characteristics

The variable socio-economic characteristics (SEC) was a combination of six socio-economic characteristics: education level of the respondent or the mother, education level of head of household, wealth index, WASH promotion, accessibility, and access to water. These six socio-economic characteristics have often been used in health and demographic surveys in

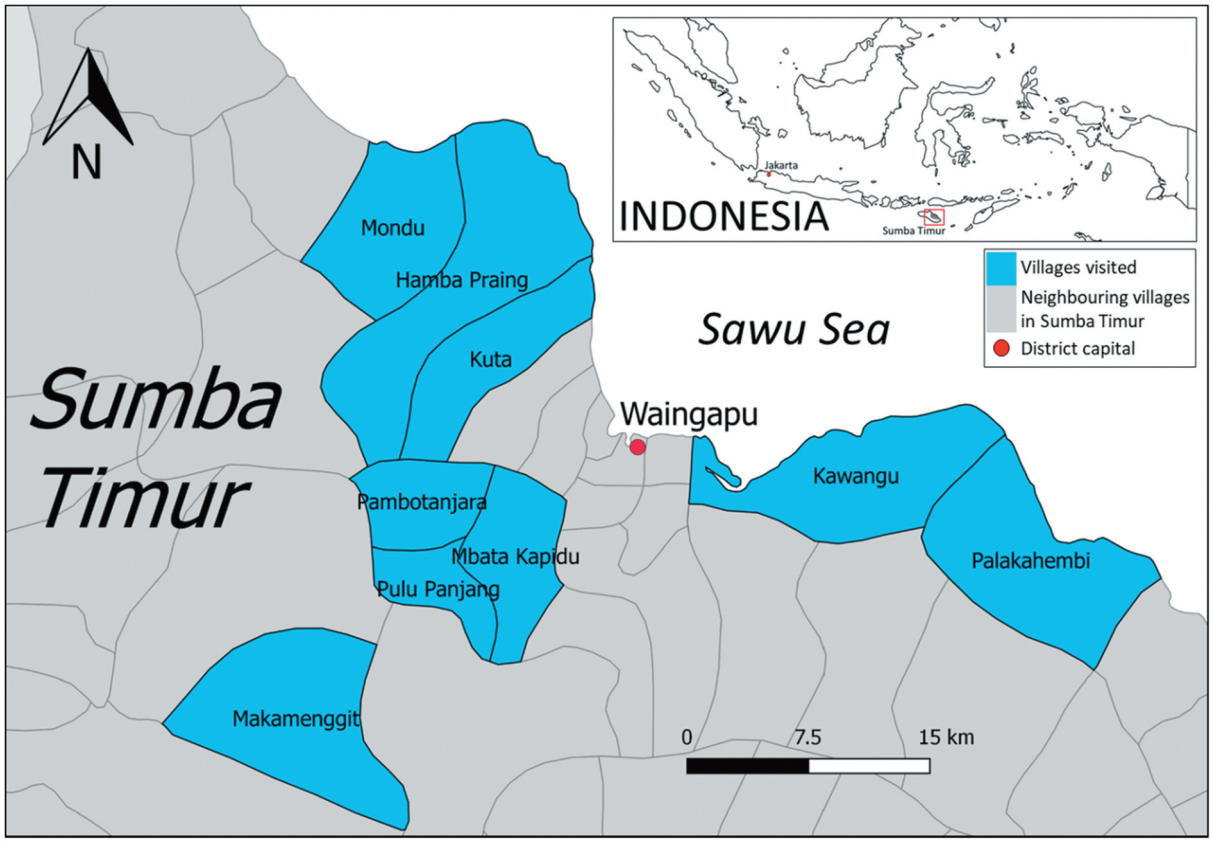

Figure 2. Location of sample communities in district Sumba Timur, Indonesia; drawn using QGIS (QGIS Development Team 2017).

a country level (ICF 2018). We assumed that these variables were a reasonable representation of respondents' SEC based on literature as described later.

Figueroa and Kincaid (2010) mentioned that access to water, access to WASH products, and mother's education are important contextual and socio-demographic predictors of HWT use. Accessibility was measured by the relative difficulty (measured by time taken) to reach the main market, i.e. difficult or easy access. Variable access to water was measured by the walking time needed to collect water, i.e. go and return. Other studies (Nauges and Van Den Berg 2009, Dubois *et al.* 2010) further mentioned that the decision-making process in a household is also important. We used the variable education level of head of household to represented them, assuming that the higher the level of education of a household head, the more rational the process of decision making in the household and therefore the higher the chance of the household choosing to use HWT. The education of both mother and household head were measured in years of education completed. Wealth represents economic ability of the family to use HWT and lack of it is often mentioned as one of the important reasons why households decide not to use HWT (Roma *et al.* 2014). Wealth was created from household assets as explained later. Households that are exposed to WASH promotion have been reported to be more likely to use HWT (Mosler *et al.* 2013, George *et al.* 2016). However, the data about WASH promotion is difficult to get from common demographic surveys. Therefore, we used frequency of watching TV to represent this variable and was measured by the frequency of watching TV daily.

In the mediation analysis we used one representative variable, SEC, which is a combination of these six variables to better measure the levels of respondents' socio-economic conditions. We assumed that the variable SEC can measure the level of "readiness" of households to adopt HWT, i.e. better SEC will facilitate more "favourable" psychosocial factors and thus higher probability of using HWT.

RANAS psychosocial variables

The RANAS model has proven capable of explaining any WASH-related behaviour, for example, the use of HWT (Inauen *et al.* 2013, Sonego *et al.* 2013, Lilje and Mosler 2017), handwashing behaviour (Seimetz *et al.* 2016), hygiene practice (Stocker and Mosler 2015), and also fields other than WASH, e.g. the Ebola-prevention behaviour (Gamma *et al.* 2017). We used five psychosocial factors of the RANAS model: Risk, Attitude, Norm, Ability, and Self-regulation (Mosler 2012). Risk represents perception and knowledge of health risks; Attitude expresses positive or negative opinions toward a behaviour; Norm represents perceived social pressure regarding the behaviour; Ability represents confidence in one's ability to execute the behaviour; and Self-regulation represents factors that are responsible for the continuation of the behaviour, i.e. self-management. Each RANAS factor contained sub-factors and the questions were at this sub-factor level (Table 1).

Output variable: "use HWT"

To better measure the level of the use of HWT, four variables were used: percentage of water treated daily, frequency of

Table 1. Descriptive statistics of psychosocial factors. M: mean, SD: standard deviation.

Psychosocial factors		Example question	Scale	M (SD)
Risk	Vulnerability	How high do you feel is the risk that you will get diarrhea if you drink untreated water?	1–5	2.9 (1.0)
	Health knowledge (1)	What are the causes of diarrheal diseases?	1–5*	1.9 (0.9)
	Health knowledge (2)	Do you know the indication of children getting diarrhea?	1–4*	1.4 (1.2)
	Severity on life	Imagine you have diarrhea, how severe would be the impact on your daily life?	1–5	3.2 (1.1)
	Severity on a child under 5 years	Imagine your child below 5 years has diarrhea, how severe would be the impact on his life and development?	1–5	3.6 (1.2)
Attitude	Health benefit	How certain are you that always treating your water will prevent you from getting diarrhea?	1–5	3.4 (1.1)
	Like taste	How much do you like the taste of treated water?	1–5	3.9 (1.1)
	Affective belief	How much do you enjoy the moment when you treat your water?	1–5	3.9 (0.9)
Norm	Descriptive	How many of your neighbours treat their water?	1–5	3.0 (1.1)
	Injunctive	People who are important to you, how do they think you should always treat your water before consumption?	1–5	3.5 (0.8)
	Personal	How strongly do you feel an obligation to yourself to always treat your water before consumption?	1–5	3.8 (1.2)
Ability	Self-efficacy	How certain are you that you will always be able to treat your drinking water before drinking?	1–5	3.3 (1.0)
	Recovery self-efficacy	Imagine that you have stopped treating your water for several days, how confident are you that you would restart treating your drinking water again)?	1–5	3.3 (1.1)
	Maintenance self-efficacy	Imagine that you have much work to do. How confident are you that you can always treat your water?	1–5	3.3 (1.0)
Self-regulation	Action control	How much do you pay attention to the resources needed to treat the water?	1–5	3.6 (0.9)
	Remembering	Within the last 24 hours: How often did it happen that you intended to treat your water and then forgot to do so?	1–5	3.8 (1.2)
	Commitment	How important is it for you to treat the water?	1–5	3.8 (1.0)
	Coping planning	Could you tell me how do you deal with the obstacles that hinder you to treat water?	1–0*	0.5 (0.5)

*For Health knowledge, the scale is based on the correct items mentioned by the respondents; for Coping planning, 1: has clear solution, 0: no clear solution.

drinking raw water daily, habit to perform HWT, and observed (confirmed) HWT at that moment. The first three were from respondent's answers during the interview and the latter was from observation of the enumerator after the interview ended. The output variable was called "use HWT." By combining multiple answers, we tried to minimize the bias of self-reported behaviour, which may overestimate the practice of HWT (Schmidt and Cairncross 2009).

Data analysis

We removed 121 data due to missing values in some of the psychosocial data in the questionnaire results. Thus, in total 256 respondent's data were used for the analysis (68% of the total sample). As all psychosocial variables in the questionnaire were at RANAS sub-factor level, principal component analysis (PCA) was performed to create one latent variable representing a specific RANAS factor by using its first principal component. For example, there are three sub-factors related to RANAS factor Norm in the questionnaire: descriptive norm, injunctive norm, and personal norm. The first principal component combines those three into one variable representing factor Norm. Similarly, the output variable use HWT was created from three answers and enumerator's observation using its first principal component (see section "Output variable").

The principal component of information on household assets was also used to create the relative wealth index. We assumed that the first principal component, Wealth, measures the wealth index of the respondents, as suggested by Houweling *et al.* (2003). Wealth was then combined with the other five socio-economic characteristics (see section "Socio-economic characteristics") in another PCA to create the variable SEC.

In PCA of the variables above, Cronbach's α value was used to evaluate how representative the principal components are of the underlying variables. A principal component is deemed acceptable if Cronbach's $\alpha > 0.7$ (Tavakol and Dennick 2011).

Mediation analysis hypothesizes that the independent variable is the cause of the mediator variable, which in turn causes or influences the dependent variable (Mackinnon *et al.* 2007). Mediation occurs when the strength of the relationship, measured by the corresponding regression coefficient, between the independent and the dependent variable is reduced or becomes insignificant when the mediator variable is included as a predictor (Fig. 1). In mediation analysis, three terms are commonly used: total effect, direct effect, and indirect effect. Total effect can be defined as: (a) the effect or influence of the independent variable (alone), as quantified by the regression coefficient, on the dependent variable without the presence of any other external or mediator variables; or (b) the sum of the indirect and the remaining direct effect of an independent variable on a dependent variable in a mediation analysis. Direct effect represents the effect of the independent variable on the dependent variable in the presence of (i.e. controlling for or keeping fixed) the mediator variables. This is obtained by regressing the latter with the dependent variable and obtaining the regression coefficients as the corresponding effects. Lastly, the indirect effect is the effect of the independent

variable on the dependent variable through a mediator variable, which is estimated by the difference between total effect and direct effect (Pearl 2001, Rucker *et al.* 2011, Hayes 2018). The mediation can be either "partial" (the direct effect is lower than total effect but *still* statistically significant) or "total" (the direct effect is lower than total effect but *not* statistically significant).

The PCA and other statistical analyses were performed using IBM SPSS statistics 25. The mediation analysis used IBM SPSS AMOS 24. The path analysis used bootstrapping with 2,000 resamples to estimate the bias-corrected 90% confidence interval.

Results

Socio-demographic characteristics of the respondents

Most of the respondents (85%) were the mothers, and the rest were the father or the oldest person available at that moment. During the household visits, 107 households (42%, n = 256) claimed that they always drink treated water. However, we observed 168 respondents (65%) using HWT at the time of visit. Almost all of the respondents (235 respondents; 92%) mentioned boiling as the main HWT method they used. Surface water was used as a main water source by 147 respondents (58%), 85 respondents (33%) relied on a piped system, and others (9%) relied on commercial, potable water, e.g. refill water, or non-potable water, e.g. water tanker. Only 55% of the respondents answered that they need less than 5 min to get water per trip, while 30% of them needed to walk more than 15 min to get water.

About half of the respondents (127) did not have children under the age of five. About half of the respondents (55%) had attended primary school, while 11% did not have any formal education and 22% had at least high school education. Similar statistics applied to the education level of the head of household: 58% had attended primary school, followed by 20% who had at least high school education, 10% had secondary school education, and 12% had no education at all. Half of the respondents (54%) answered that they hardly ever watch TV, while 31% do it often or very often. The proportions of respondents who lived in relatively easy and difficult to access areas were almost equal, 51% and 49%, respectively. Most of the respondents (85%) had non-concrete house walls, 93% had a permanent roof (not from straw or mud), and 66% had non-permanent floor (earth or soil).

Principal component analysis

The principal component (PC) of the six socio-economic characteristics obtained from PCA is SEC (Table 2). The corresponding high value of Cronbach's α suggests that these variables are sufficiently related or in agreement with each other. We therefore associated the variable SEC with the level of readiness of people to adopt HWT, where a higher value of SEC means the readiness of people to adopt HWT is also high. The PCA applied on all RANAS psychosocial factors, except Self-regulation, also demonstrated high values of Cronbach's α. The low score of Cronbach's α corresponding to PCA of Self-regulation factors implies that the PC might not be good enough to represent the level of a household's self-regulation. The PCA on the output variable use HWT yielded one PC with a high percentage of explained variance (62%, Table 2) and a high score of Cronbach's α.

Mediation analysis

Table 3 shows the one-to-one relationship between all variables. The Pearson correlation coefficient for all variables had a significant and positive relationship between all other variables, indicating that a higher level of one variable is associated with a higher level of another variable. The positive correlation between all psychosocial variables suggests an "agreement" between them, e.g. if a household has high level of perception of risk, it is expected to have a high level of perception of other psychosocial variables.

Figure 3 reveals that SEC has a significant and positive relationship with all psychosocial variables (see also Table 4, rows 1–5), implying that SEC can be used to explain the level of psychosocial variables. The better the SEC, i.e. higher readiness level, e.g. wealthier, more educated, easier access, etc., the more favourable the psychology of households with regards to using HWT. Moreover, compared to other psychosocial variables, Self-regulation had the strongest correlation with SEC ($\beta = 0.455$; $p \leq 0.001$), which implies that those households that have favourable socio-economic conditions display higher levels of self-regulation. This is further reinforced by the correlation tests between SEC and all four sub-factors of self-regulation (see Table 1), which show significant ($p \leq 0.05$) and positive correlations.

However, the mediation analysis revealed that the direct effect of SEC on the use of HWT was not significant ($p > 0.05$, Table 5, row 2), but, the total indirect effect was significant (β = 0.340, Table 5, row 3). This shows that psychosocial variables mediate the relationship between SEC and use HWT. As indicated by the largest β value when comparing the five pathways (Table 5, rows 4–8), Attitude was the most important pathway in our assessment (β = 0.151, Table 5,

Table 2. Summary of the principal component analysis (PCA) results.

Variable	KMO*	χ^2	% variance	Cronbach's α
SEC	0.722	587	45	0.703
Risk	0.744	753	60	0.805
Attitude	0.755	622	69	0.846
Norm	0.679	212	67	0.734
Ability	0.737	716	84	0.905
Self-regulation	0.663	109	44	0.535
Use HWT	0.765	449	62	0.729

*Kaiser-Meyer-Olkin (KMO) value greater than 0.5 is considered acceptable for PCA.

Table 3. Pearson correlation between all variables.

	SEC	Risk	Attitude	Norm	Ability	Self-regulation	HWT
SEC		0.222**	0.275**	0.284**	0.144*	0.455**	0.295**
Risk			0.498**	0.518**	0.535**	0.465**	0.471**
Attitude				0.599**	0.647**	0.693**	0.791**
Norm					0.652**	0.650**	0.701**
Ability						0.613**	0.703**
Self-regulation							0.712**
HWT							

** $p \leq 0.01$; * $p \leq 0.05$.

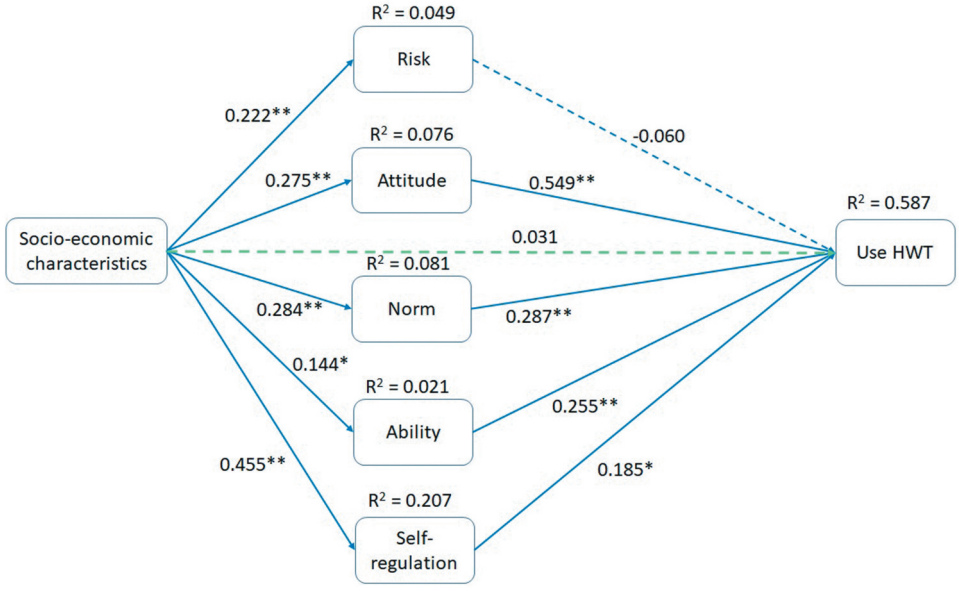

Figure 3. Summary of the mediation analysis scheme following the RANAS concept. Dashed line indicates insignificant association and solid line indicates significant association. **significant at the 0.01 level; *significant at the 0.05 level. R^2 is the variance explained by the predictor(s).

Table 4. Maximum likelihood estimates for the assumed underlying pathways. *B*: unstandardized coefficient; *β*: standardized coefficient; SE: bootstrap error; LB: lower bound and CB: upper bound for *β*, 90% confidence interval, bias-corrected bootstrap for CI (bootstrap 2000); R^2: coefficient of determination.

No.	Independent variable	Dependent variable	*B*	SE	*B*	LB	UB	R^2
1	SEC	Risk	0.208	0.055	0.222**	0.122	0.308	0.049
2	SEC	Attitude	0.263	0.050	0.275**	0.189	0.349	0.076
3	SEC	Norm	0.278	0.051	0.284**	0.199	0.361	0.081
4	SEC	Ability	0.128	0.053	0.144*	0.048	0.239	0.021
5	SEC	Self-regulation	0.462	0.051	0.455**	0.378	0.527	0.207
6	SEC	Use HWT	0.023	0.037	0.031	−0.051	0.113	0.587
	Risk		−0.048	0.038	−0.060	−0.138	0.020	
	Attitude		0.426	0.048	0.549**	0.445	0.640	
	Norm		0.218	0.044	0.287**	0.194	0.385	
	Ability		0.213	0.066	0.255**	0.133	0.401	
	Self-regulation		0.135	0.049	0.185**	0.076	0.303	

*$p \leq 0.05$, **$p \leq 0.001$.

Table 5. Total, direct, total indirect, and specific indirect effects of socio-economic characteristics (SEC) on "use HWT". See Table 4 for explanation of abbreviations.

No.	Predictor	*B*	SE	*β*	LB	UB
1	SEC → use HWT (total effect)	0.275	0.051	0.371***	0.261	0.465
2	SEC → use HWT (direct effect)	0.023	0.037	0.031	−0.051	0.113
3	SEC → use HWT (total indirect effect)	0.252	0.042	0.340***	0.259	0.429
4	SEC → Risk → Use HWT	−0.010	0.009	0.013	−0.027	0.002
5	SEC → Attitude → use HWT	0.112	0.025	0.151***	0.075	0.155
6	SEC → Norm → use HWT	0.060	0.017	0.082***	0.037	0.092
7	SEC → Ability → use HWT	0.027	0.014	0.037**	0.011	0.059
8	SEC → Self-regulation → use HWT	0.062	0.024	0.084**	0.025	0.105

*** $p \leq 0.001$; ** $p \leq 0.01$. "Total indirect effect" is the sum of indirect effects of all five pathways from SEC to use HWT via Risk, Attitude, Norm, Ability, and Self-regulation. The variables use HWT, Risk, Attitude, Norm, Ability, and Self-regulation are variables in reduced form based on PCA of a larger set of outcome and psychosocial variables. See section "Data analysis".

row 5). We also noticed that the pathway through Risk is not significant, which is indicated by the negative *β* value.

Discussion

We demonstrated that the influence of a household's socio-economic characteristics on the use of HWT is mediated by psychosocial variables. The mediation analysis showed that indirect influence was significant while direct influence was insignificant. Therefore, a "causal" relationship pathway of socio-economic characteristics influencing water use behaviour via psychosocial characteristics can be used to interpret the use of HWT. Other studies outside WASH domain have also found similar results, such as in context of smoking behaviour

(Gecková *et al.* 2005, Martinez *et al.* 2018) and adolescents' behaviour (Rodriguez *et al.* 2014).

The findings suggest a possible mechanism of how people's characteristics may influence the behaviour: the socio-economic conditions of a household shape their psychology first, which in turn influences the process of HWT adoption. The results also confirm our hypothesis that favourable socio-economic conditions of households, e.g. higher education, greater wealth, or easier accessibility, positively influence the psychology of HWT adoption.

Moreover, the direct effect of SEC on the use of HWT, which became insignificant when regressed with "use HWT" in the presence of psychosocial factors, suggests that the socio-economic characteristics should not be measured at the "same level" as psychosocial factors. This has also been emphasized in some psychological frameworks, such as a model of communication for water treatment and safe storage behaviour (Figueroa and Kincaid 2010) and health belief model (Rainey and Harding 2005). Socio-economic characteristics should therefore be considered as predictors of psychosocial factors in future studies, e.g. by using a two-level regression analysis or two layers in hierarchical Bayesian belief networks.

Comparing five pathways from SEC to use HWT, the pathway through Attitude is the most important (β = 0.151, Table 5, row 5). A previous mediation analysis also found that attitude positively influences the water consumption behaviour (Straus *et al.* 2016). It means that, in our case, emphasizing the benefits and positive experiences of using HWT by HWT users to non-user is important to influence the sustainable use of HWT. Examples include informing the target group that water quality has improved after treatment (water quality testing before-after HWT) and explaining that HWT use has long-term benefits (Lucas *et al.* 2011).

The Cronbach's α of all principal components was between 0.7 and 0.9 and is thus considered "acceptable" for a PCA (Tavakol and Dennick 2011). This means that variables on which PCA was performed were well correlated and that the extracted principal components were reliable representatives of the variables. Therefore, low Cronbach's α for the sub-factors of Self-regulation means that the principal component of the sub-factors was not a reliable and a consistent representative of a household's self-regulation. Lilje and Mosler (2018) reasoned that self-regulation is indeed difficult to measure among the respondents who have no experience with HWT, i.e. in our case, only 42% claimed to be a HWT user. This may explain the low Cronbach's α for Self-regulation.

The variable SEC explains very well Self-regulation compared to other psychosocial variables. Since the result of PCA for Self-regulation is not "trustworthy," we estimated the correlations between each of the four sub-factors of Self-regulation and SEC, and found all to be significant ($p \leq 0.05$) and positively correlated. Since Self-regulation is a factor that drives sustainable use of HWT, it seems that the six socio-economic characteristics that we used are necessary facilitators of consistent use of household water treatment. For example, economic ability and easily accessible location could facilitate Coping planning and Action control, while education and promotion could facilitate Remembering and Commitment.

In contrast, the PC "use HWT" had a high Cronbach's α and explained variance. This implies that combining self-reported and observed answers to whether a household uses HWT is a better approximation of the true behaviour than considering only one of the answers. In our case, we used three questions and one observation, inquiring about the same behaviour of using HWT. A respondent might give an answer to a question, which might not be representative of their true situation, e.g. self-reported behaviour overestimates the actual behaviour (Schmidt and Cairncross 2009). That could either be because they do not understand the question, e.g. the questions may be too technical for uneducated people, or that they give a dishonest answer due to some ulterior motives, e.g. in lieu of a gift. Our result shows that combining multiple answers can tackle this issue and provide a better assessment of the behaviour.

There are some limitations that need special attention. First, SEC explains only a small variance of psychosocial factors besides Self-regulation (see R^2 in Table 4, rows 1–5). This suggests that either other socio-economic characteristics better explain households psychology or household's socio-economic characteristics are not enough to unravel the complexity of psychosocial characteristics (Lilje and Mosler 2017). Another limitation is that we assumed causal relationships based on the correlation results, which is highly debatable (Bollen and Pearl 2013, Zhang and Zhang 2017, Contzen and Marks 2018). Third, since the sub-district selection was based on discussions with the local partner, there is a potential for selection bias. However, we tried to minimize this by doing a random sampling at the household level. Finally, the deletion of one-third of the total households from analysis due to missing values has some consequences: (a) The results do not fully represent the population in that area; (b) Even though the final sample size of 256 used for the analysis was lower than the one recommended by (Krejcie and Morgan 1970), it still met the recommendation of (Wilson Van Voorhis and Morgan 2007); (c) the socio-economic characteristics difference of the remained and deleted samples is marginally significant (Mann-Whitney U-test, U = 12,920, p = 0.06).

Conclusion

This study provides insights into the relationship between socio-economic characteristics, psychosocial factors, and one of the WASH behaviours: the use of water treatment at household level. The influence of household's characteristics on the use of HWT appears to be mediated by household psychology as represented by the psychosocial characteristics (B = 0.252; $p < 0.001$). This apparent causal mechanism to explain the use of HWT can be used in future studies, e.g. designing behavioural change campaigns. The results suggest that interventions that address important psychosocial factors, such as Attitude in our case, are necessary since the latter strongly influence the use of HWT. We also confirmed that better socio-economic conditions of the household could facilitate higher adoption of HWT. Our PCA results suggest that multiple information sources (questions) should be combined to capture the true state of psychosocial factors and consequently HWT behaviour. Combining the interview answers with observations is also recommended to reduce

the risk of getting imprecise information about the behaviour in the data collection process in the field.

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