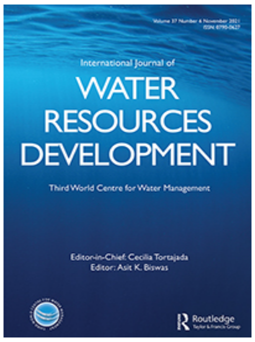
Willingness to pay for fluoride-free water in Tanzania: disentangling the importance of behavioural factors



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Willingness to pay for fluoride-free water in Tanzania: disentangling the importance of behavioural factors

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ABSTRACT
Approximately 200 million people, mainly concentrated in rural areas of the Great East African Rift Valley, suffer from fluorosis caused by excess of fluoride naturally contained in water. This study employs the RANAS (Risk, Attitude, Norm, Ability, Self-regulation) model to understand how behavioural factors influence Tanzanian rural communities' willingness to pay for fluoride-free water obtained from a new defluoridator device. Results show that perceived risk, knowledge, attitudes and descriptive norms significantly influence the adoption of the proposed healthy behaviour. Policy implications are discussed taking into account how rural communities could achieve equitable and affordable access to safe water.

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Introduction

The United Nations' Sustainable Development Goal 6.1 sets out to achieve universal and equitable access to safe and affordable drinking water for all by 2030. However, without serious policy interventions, this goal appears to be difficult to reach in regions affected by fluoride water contamination. Excessive fluoride in drinking water is currently influencing the living conditions and health status of approximately 200 million people mainly concentrated in rural areas (Akuno et al., 2019; Del Bello, 2020; WHO, 2011). The WHO (2011) suggests a safe limit for systemic fluoride intake of drinking or cooking water that should not exceed 1.5 parts per million (ppm) or milligrams per litre (mg/L). However, many studies recommend that this limit needs to be adapted to local conditions such as climate, water consumption and diet (Craig et al., 2015; Fawell & Bailey, 2006; WHO, 2011). Nevertheless, the limit of 1.5 mg/L is largely exceeded in 24 countries, many located along the so called 'fluoride belts' which stretch from Syria through Jordan, Egypt, Libya, Algeria and the Great East African Rift Valley, and extend through Sudan, Ethiopia, Kenya, Tanzania and Uganda. Further belts spread from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China (Khairnar et al., 2015; Tekle-Haimanot et al., 2006; WHO, 2011).

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The prolonged intake of fluoride-contaminated water can cause dental and skeletal fluorosis. These diseases can seriously affect teeth and bones causing pain in the joints that over time can lead to reduced mobility and in some cases to permanent disability (Fawell & Bailey, 2006; WHO, 2011). Furthermore, the impact of these diseases may lead to social and psychological disorders such as social exclusion and sense of isolation and frustration (Tekle-Haimanot et al., 2006; WHO, 2011). Dental fluorosis gives rise to discoloration of teeth, and in cases where more than 50% of surface enamel has been lost, restoring natural white enamel relies on complex and expensive interventions such as micro- and macro-abrasion or crowns (Sherwood, 2010). These interventions are time-consuming and not easily available and affordable by many members of these rural communities (Khairnar et al., 2015). The health of these populations is dramatically and irreversibly compromised by skeletal fluorosis because currently no standard treatments are available (Yang et al., 2017).

Three different water sanitation strategies are usually suggested to prevent or minimize the risk of fluorosis in these rural areas: (1) use of alternative water sources, (2) localization of low-fluoride wells or boreholes and (3) removal of excessive fluoride from drinking water (Khairnar et al., 2015; UNICEF, 2008). The first strategy is connected to the harvesting of rainwater and fog water (Ndé-Tchoupé et al., 2019). Although water from rain or fog is uncontaminated, relatively simple and low cost, this strategy usually suffers from the limited amount of storage capacity of communities and households (Onipe et al., 2020). The second strategy is based on the localization of low-fluoride content in wells and boreholes because this contaminant is usually unevenly distributed in the groundwater. However, limits to this strategy can be identified in problems connected to finding water sources that can serve rural populations living in extended isolated areas (UNICEF, 2008). The third strategy instead relies upon the development of cost-effective, sustainable and user-friendly defluoridation techniques (DTs). This strategy is considered as one of the best ways to treat fluoride-contaminated water in rural areas (Ayoob et al., 2008; UNICEF, 2008; Yadav et al., 2018). However, despite the fact that DTs can be an effective solution to provide safer drinking water and reduce the economic and health burden of fluorosis, their level of adoption remains quite low.

The low rate of acceptance of DTs has been highlighted in many studies where researchers have stressed that to enhance public health and the adoption of household drinking water treatment technologies, more research is needed to understand the mechanisms of behavioural factors that influence people's consumption of safer water. These factors can be targeted at rural communities to trigger the most effective behavioural change interventions (Burt et al., 2017; Huber & Mosler, 2013; Lilje & Mosler, 2017; Mosler, 2012; World Bank Group, 2015).

Some studies have explored how psychological components can influence the acceptance of fluoride-free services using the RANAS (Risks, Attitudes, Norms, Ability and Self-regulation) model (Huber et al., 2011; Huber & Mosler, 2013; Mosler, 2012). This conceptual framework was developed merging different health psychology theories (Fishbein & Ajzen, 2010; Floyd et al., 2000; Rosenstock, 1974). The RANAS model collects information associated with the perceived vulnerability and severity of contracting fluorosis diseases. It also takes into account the risk knowledge factor that encompasses both how an individual's awareness can be affected by fluorosis and the actions that can be taken for health protection. Attitudinal factors are connected to an individual's instrumental beliefs over their efforts and health consequences of drinking safer water. Attitudes can also have an affective component related to feelings of performing a specific behaviour (Mosler, 2012). Norms provide information on the importance of the perceived social influence on an individual's behaviour gathering information about descriptive, injunctive and personal norms. Descriptive norms explain how an individual behaves in certain ways because other people behave similarly. Injunctive norms evaluate behaviours supported by relatives, friends or neighbours. Personal norms convey individual feelings such as moral obligations. The ability factor embodies beliefs on a person's confidence in being able to perform a behaviour. Finally, self-regulation factors are responsible for perceived actions linked to the continuation and maintenance of a behaviour (Lilje & Mosler, 2017).

Furthermore, only a few studies have attempted to analyse the willingness to pay (WTP) for defluoridated water services, and two of these were located in the Rift Valley of Ethiopia (Entele & Lee, 2020; Wondimu & Bekele, 2011). Entele and Lee (2020) interviewed 330 respondents to estimate the WTP for 2 m^3 of fluoride-free water at home and at the nearest public tap in the Rift Valley of Ethiopia. The WTP was elicited using an open-ended format and estimated performing a Tobit regression. Results showed that participants were willing to pay US$13.70 (US$0.134 for 20 L of water) for fluoride-safe water at home and US$6.84 for water available from the nearest public tap (0.0684 for 20 L of water). Wondimu and Bekele (2011) also estimated the WTP for defluoridated water by performing a censored regression and interviewing 126 randomly selected households. They found that the estimated mean of the WTP for fluoride-free water was US$0.025 per 20 L of water. Both studies showed that the WTP for fluoride-free water seemed to cover defluoridation water cost services. Instead, other studies that have focused on water treatment services of different contaminants (e.g., arsenic) found a low WTP for these services which was not sufficient to introduce these devices on a large scale without the use of subsidies (Ashraf et al., 2010; Burt et al., 2017; Dupas, 2011; Luoto et al., 2012).

However, none of these studies has attempted to explore how psychological factors such as risk, attitudes and norms can influence the purchasing behaviour of individuals living in these rural communities. Thus, to the best of our knowledge, this is the first study to combine the use of the RANAS model with a contingent valuation market scenario developed to estimate the WTP for fluoride-free water obtained by a new defluoridator in a rural area of the Tanzanian Rift Valley. In this area, fluoride contamination of aquifers is very high and so is the risk of contracting dental and skeletal fluorosis (Tekle-Haimanot et al., 2006; Vuhahula et al., 2009).

As a result, we aimed to answer the following research questions:

- To what extent are individuals in these rural communities willing to pay for fluoride-free water?
- Do psychological and socio-economic factors influence the WTP for fluoride-free water obtained employing a new defluoridator?
- Which interventions can policymakers and other stakeholders put in place to improve the demand for fluoride-free water and the health of individuals?

Materials and methods

Sampling and data collection

To achieve the stated objective and to answer the research questions, a quantitative study was conducted in the Meru district situated in the Arusha region. The choice of examining this region was motivated by the fact that it has the highest concentration of fluoride in water in Tanzania, with an average of 13.57 mg/L, and with the largest number of water samples exceeding the current national fluoride standard, that is, 4 mg/L (Malago, 2017; Ndé-Tchoupé et al., 2019; Vuhahula et al., 2009). About 90% and 2% of the population in the Arusha region (1,700,000 people) suffer, respectively, from dental fluorosis and skeletal fluorosis at different stages of severity. The Tanzania Food and Drugs Authority categorized dental fluorosis as the fifth most common nutritional disorder (Vuhahula et al., 2009).

The study was targeted at Meru and Maasai, the two main ethnic groups who are representative in terms of culture, lifestyle and farming habits of rural communities living in this area. Participants included in this study were recruited randomly from eight rural villages (Engutukoit, Lemanda, Lemongo, Losinoni Juu, Losinoni Kati, Oldonyowas, Olkungwado and Uwiro) by a non-governmental organization (NGO) working in this area. The Meru are the dominant group, and their main source of income is small-scale farming, while the Maasai are semi-nomadic pastoral farmers who inhabit the dry lands. The total population in these villages is about 45,000. The survey was administered face to face by a team of experienced local interviewers hired by the local NGO, who received three days' training in techniques and ethical aspects of surveys by researchers involved in this study. The survey was piloted in June 2019 and concluded between July and August 2019 using an electronic questionnaire (a paper version of the questionnaire is available from the authors upon request) built by using the KoBoToolbox package (https://www.kobotoolbox.org) which allows researchers to collect data online and off-line. Formal consent was required from each participant before starting the investigation. The completion of the questionnaire took about 30 min, and to guarantee anonymity, no personal data were required.

The sample size was calculated using the following formula:

$$n \geq \frac{N\left(Z/_{2e}\right)^2}{N-1+\left(Z/_{2e}\right)^2} \tag{1}$$

where n represents the sample size; N is the population; Z is the Z-score; and e is the error. Thus, a sample size of 381 can be considered appropriate for a population of about 45,000 Maasai and Meru living in the eight villages of the Arusha region with a confidence level of 99% and a margin of error of ±5%.

Survey design

The electronic questionnaire was developed on the basis of insights obtained from four focus groups conducted in the same area in October 2018 (Nocella et al., 2021). The questionnaire consisted of five sections: water consumption habits, illustration of the innovative DT, psychological aspects linked to healthy drinking habits and to the use of a new defluoridator device (FDD), a contingent valuation scenario, and socio-demographic characteristics.

The first section gathered information on habits related to the consumption of water used for drinking and cooking purposes. The second section aimed at introducing participants to the new FDD (Idini et al., 2020) engineered under the 'FLOWERED' H2020 project (www.floweredproject.org). This new device supplies fluoride-free water in a friendly way taking advantage of the application of octacalcium phosphate (OCP). The FDD uses a battery that can be easily recharged by different power supplies (e.g., solar panel, power generator) allowing it to be used in rural areas not served by electricity grids. Other treatment accessories available to clean water from pathogens and possible turbidity can be easily associated with the defluoridator. Differently from other processes such as those based on bone char adsorbent materials, this new DT can treat water with an initial fluoride concentration of 21 mg/L lowering contamination well below the drinkable limit of 1.5 mg/L in 2 h with no secondary negative effects on water quality (Idini et al., 2020). The new defluoridator, available for both private households and rural communities, was presented and described by means of cards that helped interviewers explain to participants how it works and how it can drastically cut the amount of fluoride in drinking water. Interviewers made sure that participants understood that the device can reduce the risk of contracting or worsening dental and skeletal fluorosis for them and their families. They were also informed that the defluoridator was developed through a European research project and that the researchers involved in the study did not represent a private firm.

The third section aimed at collecting information linked to the RANAS model (Mosler, 2012). Risk was captured by perceived vulnerability and perceived severity. Perceived vulnerability describes a person's subjective perception of their risk of contracting a disease. Perceived severity is connected to a person's perception of the seriousness of the consequences of contracting a disease (Mosler, 2012). Furthermore, according to the RANAS model, the behaviour of a person can be influenced by their perception of how they could be affected by a disease, for example, understanding the likelihood of potential pathogen contamination and potential remedies to avoid being affected by a disease (Mosler, 2012).

Two items of perceived vulnerability measured the probability of contracting dental and skeletal diseases, while two items of severity assessed the negative consequences of these diseases on their health status. Participants' factual knowledge was tested by proposing five different precautions to respondents that aimed to investigate whether they actually knew how to prevent fluorosis (boiling water, brushing teeth, defluoridating water, taking medicine and drinking milk). Four attitude items evaluated both positive aspects of drinking defluoridated water in relation to good health, better taste, feeling happy and negative aspects in terms of time management.

Three normative items elicited information about what respondents thought other community members might do (descriptive norm), what other people thought they should do (injunctive norm) and their commitment towards heathy drinking behaviour (personal norm) if the rural community had the possibility of using the new water purification system. The ability item measured the personal capacity of an individual to carry out a healthy drinking behaviour, while five self-regulation items gathered information about plans regarding the use of these devices in terms of daily routine and commitment. Vulnerability items were evaluated on a five-point scale ranging from very unlikely to very likely; factual knowledge was captured with yes/no answers; and all the other components of the RANAS model were measured on a Likert scale ranging from completely disagree to completely agree.

The fourth section had the objective of collecting information about the WTP for this hypothetical market which could be developed to allow Maasai and Meru to obtain fluoride-free water using the FDD. In developing this part of the questionnaire, we took into account the challenges of applying contingent valuation techniques in developing countries because of lack of data, language, cultural obstacles, ability to pay and use of monetary payment for stated preference studies, and risk of implementing the wrong policies (Gibson et al., 2016; Whittington, 2002; Whittington et al., 1990).

The contingent market scenario informed participants about the features of this defluoridator that could be available as either a private or a community device. The importance of offering these two alternatives emerged from the focus group analysis. The private defluoridator had to be installed in homes and managed at a family level, and was able to defluoride one bucket of water (20 L) in 2 h. Alternatively, the community defluoridator had to be installed in a convenient location in the village, managed centrally and serve the needs of the community, and thus bigger than the private one with a capacity supply of 1000L (50 buckets) in 2 h. Both defluoridators could be used more times in a day and allowed households in these villages to satisfy their current water demand. Respondents were offered the choice between either of these two defluoridators and neither of them. Those who answered neither of these two options were redirected to a set of reasons that could explain their refusal to adopt the new technology.

The WTP for fluoride-free water was first piloted using a payment card. However, the use of this elicitation method showed an anchoring bias effect towards the lowest price bids of the proposed payment card. Thus, the payment card was replaced by an open-ended elicitation format that was linked to their usual payment habits (Bateman et al., 2002). This is because from focus group results it emerged that in this area water payments were made either as a payment for fetched buckets or as monthly payment covering maintenance costs of the water sources (borehole, well and tap). The contingent valuation scenario ended informing respondents that spending more for fluoride-free water they would have had less economic resources for other goods and services.

The last section of the questionnaire collected information about the socio-demographic characteristics of participants such as gender, age, education and their assets (electric iron, refrigerator, mattress or bed, radio, watch or clock, sewing machine, modern stove, bicycle, motorcycle, car or truck) measured on a binary variable. Assets were considered a proxy of income when interviewing people living in these poor areas of the world because information on income was difficult to collect. As a result, durable household assets were used to construct an alternative measure of welfare or living standards (Filmer & Pritchett, 2001; Montgomery et al., 2000; Sahn & Stifel, 2000). A household assets variable was constructed as the unweighted sum of the 11 items mentioned above.

Statistical and econometric analysis

Differences between Maasai and Meru on key variables such as assets and elements of the RANAS variable were performed with a series of independent sample *t*-tests. The WTP for fluoride-free water was estimated following well-known contingent valuation methods (Carson & Hanemann, 2005; Carson & Mitchell, 1993; Cummings et al., 1985; Dutta et al., 2005; Venkatachalam, 2004). In our study, the scope was to calculate the compensating or equivalent variation from the actual status of quality of water q_0, to a fluoride-free level of quality q_1. Thus, the WTP for fluoride-free water will be equal to the amount of income that an individual must give up to compensate for the increase in the quality of water from q_0 to q_1, that is:

$$V(y - WTP, p, q_1; Z, X) = V(y, p, q_0; Z, X),\ q_1 \geq \mathrm{q}_0 \tag{2}$$

where *V* is the indirect utility function; *y* is income; *p* is the water price vector faced by an individual, which could be, or not, determined in the market; *X* is the vector of socio-demographic characteristics of participants; and *Z* is the vector of the psychological variables of the RANAS model.

The WTP was estimated employing a Tobit censored regression model because the distribution of stated monetary values is positive, continuous and censored at zero (Green, 2019; Tobin, 1958). Furthermore, we also performed a censored quantile regression to estimate the impact of the socio-economic and RANAS variables on various percentiles of the WTP distribution (Powell, 1986). A Laplacian estimator of the censored quantile regression was implemented to estimate the simulated joint distribution of the parameters via an adaptive Markov chain Monte Carlo method. Thus, the estimation of the censored quantile regression allows for a more wide-ranging view of the relationship between the dependent variable and the covariates, since the impact of covariates vary at each percentile of the conditional distribution of the WTP. Further, censored quantile regression is more robust than Tobit regression in the case of possible outliers and/or fat tails of the WTP distribution. This is a property particularly useful in the context of contingent valuation studies where high WTP bids or large numbers of small bids can frequently occur (Kowalski, 2016; O'Garra & Mourato, 2006).

The contingent valuation was first piloted in February 2019 involving 30 participants, where the elicitation WTP format was fine-tuned and other bugs were eliminated.

Results

Socio-demographic and economic characteristics of respondents

A total of 14 of the 700 electronic questionnaires collected by interviewers were discarded because they were incomplete or contained compilation errors, and thus only 686 participants were included in the final sample size. Table 1 shows that 84.3% were Meru and 15.7% Maasai, and this distribution reflects the share of two ethnic groups living in this area. As the survey was targeted at family members in charge of water consumption and management, 78.3% of participants were females because they are those usually heavily involved in fetching water in Sub-Saharan African countries (Graham et al., 2016).

Table 1. Socio-demographic and economic characteristics of respondents (N = 686).

Socio-demographic variables	Mean	SD	Respondents
Ethnic group			
Meru			578
Maasai			108
Gender			
Female			537
Male			149
Age	41.23	14.79	686
Number of persons living in the household	5.59	2.84	686
Education			
No education			278
Primary, secondary education or higher			408
Economic conditions			
Does your family own any of the following items (include only if they are in working condition)?			
Electric iron (yes)			11
Refrigerator (yes)			3
Television (yes)			101
Mattress or bed (yes)			650
Radio (yes)			399
Watch or clock (yes 1)			149
Sewing machine (yes)			20
Modern stove (yes)			65
Bicycle (yes)			32
Motorcycle (yes)			80
Car or truck (yes)			5
None of these			30
How often in the last year, did you have problems satisfying the food needs of the household?			
Never–sometimes			442
Often			244
Total acres of land owned	2.04	2.97	686
Total number of cattle owned	6.71	10.61	686
Total number of sheep owned	9.26	16.52	686

The average age of respondents was 41 (s = 14.8), with an average family size of six members (s = 2.8). The mean of the durable assets obtained after having performed the test of reliability (Cronbach's α = 0.62) was 2.20 (s = 1.37). A comparison between the two ethnic groups shows that Meru have on the average more assets ($\bar{x}$ = 2.34; s = 1.38) than Maasai ($\bar{x}$ = 1.45; s = 1.13). This difference was significant to the independent sample t-test (t =6.36; d.f. = 684; p = 0.0001). However, Maasai's land and livestock ownership was higher than that of Meru. As Maasai are a semi-nomadic pastoral people, they reported an average of 3.01 acres and 29.6 cattle (s = 36.53), while Meru had on average 1.85 acres and 13.41 cattle. Also, these differences were significant to the independent sample t-test for land (t = 3.73, d.f. = 684, p = 0.001) and for livestock (t = 6.76, d.f. = 684, p = 0.001). The majority of participants had problems in satisfying their daily food needs and the Meru emerged as being more affected by food insecurity (68%) than Maasai (50%).

Water consumption habits

Table 2 shows that the main sources of water for participants were public outdoor taps and boreholes (75%), followed by wells (19%), water piped into dwellings and compounds served a small number of households (4.2%), and 1.8% of participants declared that they fetched

Table 2. Water consumption habits (*N* = 686).

Water consumption and habits variables	Mean	SD	Respondents
Water payment method			
Current monthly payment (TZS, thousands)	0.91	1.23	565
Current monthly payment (US$)[a]	(0.39)		
Current price per bucket (20 L) (TZS, thousands)	0.06	0.15	121
Current price per bucket (20 L) (US$)[a]	(0.03)		
Water sources			
River, lake, pond			12
Well			127
Public outdoor tap or borehole			518
Piped into dwelling or compound			29
Days fetching water in a week	5.97	1.70	686
Number of buckets	2.35	1.32	686
Per capita water consumption in a day	8.75	6.79	686
How long in minutes does it take from your home to reach your main supply of drinking water on foot?			
0–14			271
15–29			262
30–44			96
45–59			31
60+			26
How do you transport the water to your house?			
On foot			519
Donkey			31
Donkey and on foot			132
Bicycle, motorcycle and car			4
Have you or your family suffered of the following diseases?			
Tooth pain (yes)			582
Back pain (yes)			448
Drinking and cooking water			
How dirty is drinking and cooking water that you consume every day? (Not dirty – Very dirty)	1.30	1.12	686
Have you or someone in your family ever purchased filtered water? (No 0, Yes 1)	0.48	0.50	686
Type of filter			
What type of filter would you and your family prefer most? (Community 0, Private 1)	0.37	0.48	686

Note: [a]US$1 = TZS 2320.4, 12 October 2020.

water directly from a river, lake or pond. On average, every day women employed 21 min to fetch 2.4 buckets of water (48 L) for drinking and cooking. Furthermore, 76% participants asserted that the trip to collect water was usually carried out without the use of a vehicle or help from animals, thus highlighting the physical effort necessary to satisfy this basic need but also the impact on the quality and volume of water that they can carry. Taking these data into account, the average per capita daily consumption of drinking and cooking water was 8.8 L (s = 6.79), which is slightly more than the 7.5 L of minimum water necessary for hydration and incorporation into food for most people and conditions (WHO, 2011).

Many respondents considered the water they consume to be dirty, and only about 28% stated that it was clean. Furthermore, despite their experience with toothache and back pain, two diseases usually connected with dental and skeletal fluorosis, only 48% had consumed defluoridated water. With respect to the price of water, the majority of respondents (53%) stated that they do not pay anything for water, and 38% declared that they usually pay a monthly fee without any specific constraints on the amount they can collect. The average monthly fee was TZS 908 (Tanzanian shillings) (US$0.39); the rest of the participants pay for water by the bucket, with an average price of TZS 59 (US$0.025).

As a method of payment, a monthly fee was reported by 565 participants. Mostly Meru (80%) stated this method, but also the majority of Maasai (67%) because many wells and boreholes in the area were built by NGOs and other donors to provide water for the villages. Therefore, community-based water management methods were usually adopted, sometimes without constraints on the amount of water that can be fetched by each household, but with the commitment to contribute to the cost of maintenance of the water sources.

Ethnic differences of Risk, Attitudes, Norms, Ability and Self-regulation (RANAS)

Table 3 presents the descriptive statistics of the components of the RANAS model and relative differences between Maasai and Meru for the psychological constructs obtained by summing and averaging the items of each component. These differences were tested by performing an independent sample *t*-test on the average summation score of the items of RANAS elements obtained after having checked for reliability.

Table 3. Comparison of results of RANAS elements between Maasai and Meru.

	Meru (N = 578)		Maasai (N = 108)		
RANAS items and latent components	Mean	SD	Mean	SD	*t*-test
Perceived risk (Cronbach's α = 0.77)	2.27	0.56	2.38	0.50	−1.94
How likely or unlikely is that you will develop dental fluorosis?	1.17	1.16	1.53	1.13	
How likely or unlikely is that you will develop skeletal fluorosis?	1.19	1.17	1.63	1.14	
If I had dental fluorosis this would affect my health severely?	3.32	0.61	3.17	0.46	
If I had skeletal fluorosis this would affect my health severely?	3.38	0.51	3.19	0.44	
Risk knowledge (Cronbach's α = 0.84)	0.48	0.25	0.40	0.21	**3.24***
Questions about how to prevent getting dental or skeletal fluorosis					
Boiling water before consuming it (No 1, Yes 0)	0.57	0.49	0.47	0.50	
Defluoriding water before consuming it (No 0, Yes 1)	0.41	0.49	0.55	0.50	
Taking medicine (No 1, Yes 0)	0.43	0.50	0.31	0.47	
Brushing teeth (No 1, Yes 0)	0.58	0.49	0.54	0.50	
Drinking milk (No 1, Yes 0)	0.42	0.49	0.13	0.34	
Attitudes (Cronbach's α = 0.70)	3.07	0.35	3.07	0.28	−0.09
Drinking filtered water from this new filter will be good for my health	3.36	0.52	3.23	0.44	
Obtaining drinking filtered water from this new filter will be time consuming	2.37	1.33	2.78	1.27	
Drinking filtered water from this new filter will taste better than the water that I usually drink	3.14	0.83	3.01	0.70	
Drinking filtered water from this new filter will make me feel happy	3.38	0.51	3.25	0.49	
Norms					
Descriptive: If your community had the possibility of using this new filter system, most people will be consuming filtered drinking water	3.37	0.51	3.24	0.45	
Injunctive: If your community had the possibility of using this new filter system, most of my neighbours will think that I should consume filtered drinking water	3.17	0.75	3.13	0.43	
Personal: If your community had the possibility of using this new filter system, I would feel a strong personal obligation to consume filtered drinking water	3.25	0.47	3.09	0.48	
Ability					
I believe I will have the ability to use this new filter system regularly	3.29	0.65	3.14	0.48	
Self-regulation (Cronbach's α = 0.87)	3.30	0.43	3.15	0.31	**3.39***
I would have a detailed daily plan on how to use this new filter system	3.27	0.45	3.07	0.43	
I would have a detailed plan on what to do if this new filter system breaks	3.34	0.51	3.24	0.45	
I feel that the use of this new filter system will become an ingrained habit	3.25	0.57	3.10	0.30	
I would feel committed to use this new filter system every day	3.34	0.52	3.19	0.40	

Note: **p*-value significant at <0.05 level.

For risk vulnerability and risk severity, both ethnic groups seem to show low vulnerability and a high severity perception. Maasai appear to be more susceptible than Meru to these diseases, while Meru considered the impact of dental and skeletal fluorosis more severe than Maasai. However, aggregating the four items as an average score, these differences were not statistically significant to the *t*-test for independent samples.

The knowledge score ($\alpha = 0.84$) shows that both ethnic groups have a low understanding of how to reduce the risk of getting fluorosis, with Maasai showing less knowledge than Meru ($t = 3.42$; $p = 0.001$). For example, only about 55% of Maasai and 41% of Meru thought that water defluoridation could reduce the risk of fluorosis; 46% of Maasai and 42% of Meru believed that brushing teeth could reduce the risk of dental fluorosis; 69% of Maasai and 57% of Meru thought that by taking medicine they could solve this problem; and 87% of Maasai and 58% of Meru believed that drinking milk could protect them from dental fluorosis. From the focus group analysis, it emerged that Maasai protect children from fluorosis by giving them only milk and no water until they are 2–3 years of age. According to Wondwossen et al. (2006), during the first two years of life, which coincide with the period of most active enamel formation, breastfeeding would seem to provide the ideal prevention of fluoride damage to teeth. However, other studies highlight that milk could be another source of fluoride intake (Gupta et al., 2015).

Participants showed positive attitudes towards the impact of drinking defluoridated water on their health, taste, happiness and time necessary to obtain it. In addition, in this case we do not observe significant differences between Maasai (3.06) and Meru (3.07) on the attitude construct ($\alpha = 0.70$). Furthermore, descriptive, injunctive and personal norms indicate that these rural communities receive enormous pressure to adopt the defluoridator if this device were available. The average scores show that the majority of respondents agreed or strongly agreed with the norms and we do not observe significant differences between Maasai and Meru. On average participants perceived that they were able to use the filter and to control the process of obtaining fluoride-free water without major problems. The self-regulation construct score ($\alpha = 0.87$) for Meru (3.30) is higher than that of Maasai (3.15), with this different significant to the independent sample *t*-test ($t = 3.39$; $p = 0.001$).

The determinants of WTP for fluoride-free water

None of the respondents refused to state how much they were willing to pay for defluoridated water. Results showed that on average Maasai's WTP for the monthly payment is higher (TZS 3209, US$1.38) than that of Meru (TZS 2853, US$1.23), while for payment by bucket Meru (TZS 167) are willing to pay more than Maasai (TZS 123), but these differences were not significant to the independent sample *t*-tests. We also observe that the stated WTP for both methods of payment is about three times higher than what they were paying for the current consumption of water. Furthermore, for the monthly payment only five respondents stated zero WTP, while for bucket payment 50 respondents stated that they were not willing to pay for defluoridated water.

Table 4 compares the WTP estimates obtained by using the STATA 17 package of four censored regression models performed on a Tobit model (M1) and on other censored quantile regressions at the 25th (M2), 50th (M3) and 75th (M4) percentiles. Table 5 presents the WTP at different percentiles. For example, the stated WTP identified at the

Table 4. Willingness-to-pay (WTP) estimates for fluoride-free water obtained from censored regressions (N = 565).

				Censored quantile regressions[b,c]					
		Censored Tobit M1[a]		25% Quantile M2		50% Quantile M3		75% Quantile M4	
Variables	Cronbach's alpha	β	p-value	β	p-value	β	p-value	β	p-value
RANAS psychological factors									
Perceived risk (vulnerability and severity)	0.76	**0.39**	0.01	**0.36**	0.00	**0.35**	0.00	**0.72**	0.00
Knowledge	0.81	**0.55**	0.00	**0.46**	0.00	**0.79**	0.00	**0.61**	0.00
Attitude	0.80	**0.75**	0.00	**0.75**	0.00	**0.84**	0.00	**1.04**	0.00
Descriptive norms		**−0.60**	0.00	**−1.13**	0.00	**−0.56**	0.00	**−0.39**	0.00
Injunctive norms		0.06	0.63	0.12	0.10	0.01	0.90	0.00	0.98
Personal norms		−0.15	0.45	−0.12	0.30	−0.15	0.17	−0.11	0.54
Ability		0.18	0.30	0.16	0.44	0.14	0.31	**0.26**	0.01
Self-regulation	0.84	−0.15	0.33	−0.08	0.54	−0.14	0.28	−0.16	0.24
Demographic and socio-economic variables									
Age		−0.01	0.20	0.00	0.85	**−0.01**	0.28	−0.01	0.04
Education		0.01	0.93	0.07	0.59	**−0.03**	0.01	**−0.36**	0.00
Assets owned	0.64	0.09	0.56	−0.01	0.95	−0.01	0.78	0.13	0.31
Land owned and rented (acres)		**0.18**	0.04	0.17	0.27	0.30	0.89	**0.20**	0.02
Dummy: Meru – Maasai (Maasai = 1)		−0.06	0.79	0.04	0.73	**−0.16**	0.00	−0.16	0.12
Dummy male – female (male = 1)		0.03	0.85	0.11	0.48	**−0.01**	0.00	−0.12	0.43
Dummy: past experience of tooth pain		0.36	0.06	**0.58**	0.00	0.40	0.91	**0.40**	0.00
Dummy: past experience of back pain		**0.66**	0.00	**0.47**	0.00	**0.82**	0.00	**0.59**	0.00
Dummy: past experience of drinking defluoridated water		**0.98**	0.00	**1.75**	0.00	**1.01**	0.00	**1.01**	0.00
Constant		1.31	0.28	**1.01**	0.00	**1.29**	0.00	**1.21**	0.00
Log-likelihood		−1025.2							
Likelihood ratio $\chi^2(22)$ test		234.63 (0.00)							

Note: [a]Estimates significant at the 5% level are shown in bold.
[b]p-value in parenthesis.
Source: [c]Powell (1986).

Table 5. Willingness to pay (WTP) for monthly payments at different percentiles of the distribution.

Percentiles	WTP at the percentile (TZS)	95% Confidence interval (TZS)	
25th	1500	1000	1500
50th	3000	2500	3000
75th	4500	4000	5000

75th percentile is greater than 75% of the WTP stated values, and smaller than the remaining 25% of the WTP stated values (for extended results, see the supplemental data online). We ran these regression models only for the maximum monthly payment that respondents were willing to pay for defluoridated water because for payment by buckets there were not enough cases. As we performed the censored regression analysis only for the monthly payment (565 cases), Table 4 reports again the Cronbach's α statistics for the reduced sample. The new values for the Cronbach's α confirm that these statistics are equal or well above the suggested minimum threshold of 0.70 (Cortina, 1993; Field, 2018) .

Results of M1 show that the elements of the RANAS model, injunctive norms, personal norms, ability and self-regulations were not significant, while perceived risk, the knowledge index, attitudes and descriptive norms were strongly significant. The sign of the β parameters of perceived risk ($\beta = 0.39$, $p < 0.01$), knowledge index ($\beta = 0.55$, $p < 0.01$) and attitudes ($\beta = 0.75$, $p < 0.01$) are positive and in line with the RANAS conceptual framework. Thus, if the scores of perceived risk, knowledge and attitudes increase by 1, participants would be willing to pay TZS 390, 550 and 750 more for defluoridated water, respectively. Instead, the β value of descriptive norms is negative ($\beta = -0.60$, $p < 0.01$) with participants paying TZS 600 less when this score increases by 1. Thus, the higher the consumption of defluoridated water in the village, the lower the expected price for this good will be. The direction and significance of the RANAS elements appear to be robust across the other three censored regression models (M2–M4), highlighting the stability of the psychological components in the estimated models. However, Table 4 shows that the magnitude of these coefficients changes in M2–M4. Comparing the β coefficients of the censored quantile regressions with the Tobit model, we observe that the magnitude of β values for attitudes and knowledge are higher in M3 and M4 than in M1, for perceived risk are higher in M4 than in M1, and for descriptive norms are higher in M1 than in M2–M4.

The socio-demographic and economic characteristics of respondents do not have a strong influence on the WTP for defluoridated water, because even if they are significant in some models, the magnitude of their parameters is very close to zero and thus irrelevant in terms of the WTP. However, it is interesting to observe the significance and negative sign of gender in M3, education and the ethnic group in M3, and age in M4. Only the ownership of land in acres is significant and positive in M1 and M4. Interestingly, we observe some significant and positive influence of previous experience on both health problems related to fluorosis and a strong and significant impact of past consumption fluoride-free water in all four models. For example, participants who had consumed defluoridated water were willing to pay TZS 980 in M1 and TZS 1750 more in M2, while in M3 and M4 the values are around TZS 1000.

Discussion and conclusions

This study focused on the water sources available in the rural Rift Valley area of Tanzania which are mainly provided through boreholes and wells that generally supply contaminated high-fluoride water. In this environment, the use of cost-effective, sustainable and user-friendly DTs can be considered the best way to provide fluoride-free water (Ayoob et al., 2008; UNICEF, 2008; Yadav et al., 2018) as residents do not have access to centralized water systems and other purification techniques proved not to be so efficient (Onipe et al., 2020). Thus, understanding factors that can influence households' WTP for fluoride-free water provided by a new DT system can help policymakers to plan and predict the effects of strategies and policies devoted to enhance the use of DTs.

The most interesting result of this study is that behavioural factors such as perceived risk, knowledge, attitudes and descriptive norms had a highly significant impact on the WTP for fluoride-free water obtained from the use of the proposed new defluoridator. Instead, the socio-economic characteristics of participants only played a minor role in explaining the variance of the WTP. This an important aspect of this study because, according to Mosler and Contzen (2016), once key psychological factors of the RANAS model have been identified, strategies and policies can be designed and put in place to induce behavioural changes. Previous studies have explored the motivations surrounding the adoption of defluoridator devices without taking into account financial considerations (Huber et al., 2011; Huber & Mosler, 2013), while our WTP parameter estimates can bring insights to policymakers about the tools necessary to induce behavioural changes.

Estimates of the knowledge parameter suggest that the dissemination of information about fluorosis diseases across rural communities of the Rift Valley of Tanzania can strongly affect the WTP for safer water. For example, increasing the knowledge score by 1 point, participants were willing to pay US$0.24 more per month to consume of fluoride-free water. Also, the parameter of perceived risk of being vulnerable or severely affected by fluorosis diseases the influenced WTP positively, especially for the 75th censored quantile regression where the magnitude of the parameter was about double the one for the 25th censored quantile regression. In this case, increasing the score of perceived risk by 1, the WTP per month of fluoride-free water increases by US$0.34 per month for the 75th quantile.

Behavioural changes can be induced by information strategies aimed at increasing knowledge in rural populations and enhancing their awareness of health problems connected to the intake of contaminated high fluoride water. Madajewicz et al. (2007) suggest that households should be informed individually about the risk of consuming water contaminated by arsenic. They found that house-to-house information strategies were very effective as 60% of families informed about their vulnerability to arsenic contamination switched to a safer well, while in households that did not receive similar information only 8% adopted a healthy drinking behaviour. Similar results were found by Jalan and Somanathan (2008) who noted that lack of information of being affected by contaminated water with faecal bacteria negatively affected the adoption of purification techniques. They found that after having informed households on this issue, they were more likely to adopt the water purification behaviour than households who had not been informed.

Thus, the first strategy emerging from this study is that policymakers should invest more in educational programmes. The objective of these information remedies is to increase the awareness and knowledge of these rural communities about health problems related to the intake of fluoride-contaminated water. Educational programmes based on house-to-house meetings, as well as to influence the WTP for fluoride-free water, should positively improve an individual's assessment of fluorosis health risks and sensitivity towards the problem.

Attitudes towards the consumption of defluoridated water was the strongest WTP parameter for significance and magnitude. This result highlights the importance of instrumental beliefs in terms of time dedicated to the adoption of a healthy drinking behaviour, the taste of water, and modifications on a respondent's health and lifestyle introduced by the use of the new defluoridator. It also considers the importance of affective beliefs which are related to feelings of happiness connected to the use of the defluoridator and the consumption of safer drinking water (Lilje & Mosler, 2017). Time spent in purifying water was the weakest item of the attitude construct. This could be connected to a possible trade-off between the involvement of households in production activities that can limit the time respondents have and are willing to commit to water treatment. Policymakers could organize participatory meetings to explain that the time they must spend to obtain defluoridated water outweighs the monetary and health costs caused by fluorosis. Communication strategies could be tailored to women, because they are generally in charge of fetching and treating water, through the dissemination of brochures or organization of working groups. Although the gender variable was not significant in this study, the effectiveness of information might also depend on whether the information is targeted at women or men (Dupas, 2011).

The negative relationship between descriptive norms and the WTP for fluoride water corroborates the findings observed by Huber and Mosler (2013). The perceived lower water costs associated with the presence of economy of scale with the use of a community defluoridator, which was the most preferred technology by the majority of respondents, could explain this result. Furthermore, it could be possible that most participants perceived the decontaminated water as a public good and thus their WTP was perceived as a contribution towards the provision of a public service. A situation like this may have given participants an incentive to rely on the expected higher contribution of others or may introduce a lack of 'trust in other people's cooperation' (Liebe et al., 2010; Ostrom, 2000). Individuals who do not believe in other people's 'payments' are less likely to be willing to pay than individuals who do believe in other people's payments. Observing the quantile regressions results, we note that this negative relationship is a common denominator of all WTP models. However, the negative impact on the WTP is lower for respondents who had a higher WTP for safe water. As a result, policymakers could adopt communication strategies aimed at increasing trust in other people's cooperation. Involving people living in the same village in the choice and location of the deflouridation device, or the introduction of equitable payment commitments, may raise trust in people's cooperation reverting the negative impact of norms on their WTP (Blamey, 1998).

Moreover, from a public health perspective, behavioural change techniques could be coupled with different policies such as mandates and subsidies that could increase the consumption of fluoride-free water (Dupas, 2011). For example, the introduction of mandates that legally impose the consumption of drinking fluoride-free water could be a good strategy if tailored to rural communities that can afford the price of this good. However, this policy seems difficult to introduce because of the low-income status of Maasai and Meru households living in this area. Instead, the introduction of price subsidies (Kremer & Glennerster, 2011) linked to behavioural change strategies devoted to increase the risk perception to contract fluorosis can facilitate the adoption of a healthy behavioural change, that is, drinking safe water. Even if such an instrument imposes a sacrifice on behalf of the government and taxpayers, this type of intervention could be temporarily in place until drinking safe water has become an ingrained habit of households living in this area of the world.

Our estimates also indicate that the average WTP for fluoride-free water obtained from a new DT is US$1.26 per month, and according to the Ministry of Finance and Economic Affairs, R. o. T. (2009), this value accounts for 9% of their average monthly household rural income. A low WTP for fluoride-free water was also observed by Entele and Lee (2020) who reported a daily WTP of US$0.064 for a fluoride-free bucket fetched from the nearest public tap in the Rift Valley of Ethiopia. When converting their WTP into monthly consumption we observe a WTP of US$1.60, which is not so distant from our estimated WTP. Thus, the estimated WTP for fluoride-free water is not high enough to introduce the new DT in Maasai and Meru communities because it starts to be economically convenient at US$33 per month (Idini et al., 2020). As a result, in these rural communities it would be impossible to cover the production costs of the fluoride-free water necessary to satisfy current households' needs.

In conclusion, although strategies and policies can be designed and put in place to induce behavioural changes aimed at increasing the WTP for fluoride-free water, without substantial health policy interventions achieving universal and equitable access to safe and affordable drinking water for all by 2030 (Sustainable Development Goal 6.1), it will be very difficult to get rid of fluorosis diseases in this part of the world. To help rural communities of the Tanzanian Rift Valley to achieve this goal, the government and donors could facilitate the adoption of new technology by investing in projects acting on the elements of the RANAS model after having introduced defluoridators to these villages. Finally, to evaluate the net benefits of these policy interventions, future studies should also assess the costs of actions necessary to trigger the behavioural change of households living in this area of the world.

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