Valuing excess fluoride removal for safe drinking water in Kenya

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Abstract

The study uses contingent valuation framework to assess the welfare benefits of removing excess fluoride from drinking water among households in Baringo County, Kenya. A conventional payment card is used to draw preferences from households in order to estimate the mean and median willingness to pay for excess fluoride removal from drinking water in the county. Through interval regression analysis, the study found that households were, on average, willing to pay Kshs. 202.25 ($2.02) and a median of Kshs. 162.50 ($1.63) to remove excess fluoride from drinking water. The mean and median welfare values of removing excess fluoride from water were estimated at Kshs. 112.4 ($1.12) and Kshs. 90.3 ($0.90) million, respectively. These amounts were significantly found to increase with male gender, education, household income, living in own house, type of water source, perceived water quality, distance to nearest water source, payment vehicle used and whether household members had suffered from fluorosis. However, these amounts declined with age and household size. On the whole, the study found significant public support towards the removal of excess fluoride in drinking water among the concerned households, which is vital for effective formation and implementation of water quality improvement policies for the county.

Keywords: Contingent valuation; Excess fluoride; Payment card; Willingness to pay

Introduction

Safe water is considered basic for both human health and survival. It is used for drinking, and for many other domestic and agricultural activities including cooking, washing, bathing and watering farm lands (Dixon & Shackley, 1999; Shomar *et al.*, 2004; WHO, 2006; Allan, 2011). As such, poor access to safe water not only affects these activities directly but also households' health and workforce productivity indirectly. Whereas the provision of safe water has gradually been on the rise around the globe, its provision in many developing and less developed countries has remained a big challenge (UNDP, 2006; WHO, 2006; WHO & UNICEF, 2012). One major challenge encountered in the

provision of safe water in most developing countries has been the occurrence of huge amounts of fluoride in drinking water that leads to fluorosis (Reddy *et al.*, 2010; Shomar *et al.*, 2004; Sudhir & Bashir, 2006; UNDP, 2006; WHO, 2006).

Notably, fluorosis is a condition that results from overexposure to fluoride in drinking water or in food stuffs produced with fluoride (Dixon & Shackley, 1999; Wambu *et al.*, 2013). It is endemic in over 25 countries across the globe and millions of people have been found to suffer from fluorosis (Sudhir & Bashir, 2006; UNDP, 2006). The health hazards resulting from fluorosis range from the less severe forms of dental mottling to severe skeletal fluorosis causing paralysis of the lower limbs (Shomar *et al.*, 2004; Sujana *et al.*, 2009; Wambu & Muthakia, 2011). The severity of fluorosis is determined by many factors, such as the duration of exposure, the socio-economic status of the community and the intake of locally grown food items, with the severity being increased by a lack of dietary calcium and essential vitamins (Kahama *et al.*, 1997; WHO & UNICEF, 2012; Wambu *et al.*, 2014). As a measure for reducing the exposure to fluoride, defluoridation of drinking water has been advocated as an alternative approach to address the adverse problems of excessive fluoride ingestion (Kahama *et al.*, 1997; Gikunju *et al.*, 2002; Mavura & Bailey, 2002; Moturi, 2004; Shomar *et al.*, 2004; Njenga *et al.*, 2005; WHO, 2006; Sujana *et al.*, 2009; Wambu *et al.*, 2013).

In Kenya, it is estimated that millions of people are at risk of serious bone defects and dental discolouration as a result of high levels of fluoride in their drinking water (Njenga *et al.*, 2005; Sudhir & Bashir, 2006; Wambu *et al.*, 2013). The risk is particularly made worse by the fact that, as the rest of the world moves to treated and piped water systems, more than half of Kenyans still rely on underground water as their primary source of drinking water (Wambu & Muthakia, 2011). This is despite warnings by researchers (Naslund & Snell, 2005; Wambu *et al.*, 2013) that most of Kenya's underground water contains fluoride levels higher than the 1.5 mg/L recommended by the World Health Organization (WHO, 2006). Consequently, about 19 million Kenyans suffer from fluorosis, a condition that can affect the teeth or skeleton, depending on the length of time one has been exposed to water with a high concentration of fluoride, and their geographical location (Gikunju *et al.*, 2002; Njenga *et al.*, 2005; Wambu & Muthakia, 2011).

The most significant sources of fluoride exposure are located in the Rift valley (Kenya Bureau of Standards (KEBS), 2010). Recent studies in the country have further established that a greater population in many parts of the Rift Valley are predisposed to fluorosis due to exposure to greater proportions of fluoride in drinking water (Gikunju *et al.*, 2002) and in other beverages such as raw vegetable juices (Mavura & Bailey, 2002; Njenga *et al.*, 2005). According to KEBS (2010), parts of the Rift Valley predisposed to fluoride levels of greater than 1.5 mg/L include Kajiado, Kericho, Laikipia, Nakuru, Narok and Baringo. While these areas are known to have drinking water containing high levels of fluoride and the resultant effects like dental and skeletal fluorosis, not much is known about the preferences of the households in supporting a policy framework that would reduce fluoride levels in drinking water. Notably, previous research on water fluoride has mainly focused on the physical distribution of fluoride (Gikunju *et al.*, 2002; Moturi *et al.*, 2002; Marieta, 2007; Wambu *et al.*, 2014), health effects of excessive water fluoride intake (Shomar *et al.*, 2004; Ayoob & Gupta, 2006; Redda *et al.*, 2006; Sujana *et al.*, 2009) and on the different procedures available for removing fluoride from drinking water (Wambu & Muthakia, 2011; Chelangat, 2015).

Recent empirical research on Baringo indicates that the majority of the population in the county have poor access to safe water (Naslund & Snell, 2005; Marieta, 2007). Drinking water that is available is sourced from lakes and rivers with high fluoride levels ranging between 10 and 20 mg/L of water, far above the standard 1.5 mg/L recommended by the World Health Organization. In addition, intake

of such high levels of fluoride has led to the increased prevalence of crippling skeletal fluorosis and dental discolouration among the local population. Skeletal fluorosis and dental discolouration have, in turn, limited the socio-economic opportunities available to people who mainly depend on agriculture and livestock for their livelihood (Mavura & Bailey, 2002; Marieta, 2007). Despite these challenges, there is no specific policy framework that has been formulated to address the issue of excess fluoride in drinking water by the county government. There is also no study known to the authors that has attempted to analyse households' preferences towards the reduction of excess fluoride in drinking water, and hence, estimate the welfare benefits of such an undertaking. Therefore, the current study was designed to bridge this policy gap with a case application to Baringo County.

This case application was chosen in order to shed more light on households' preferences towards the removal of excess fluoride from drinking water and, therefore, estimate the welfare benefits of formulating and implementing a policy framework that would address the health concerns facing the local population concerning excessive ingestion of fluoride in drinking water. To achieve this objective, contingent valuation (CV) methodology was employed. The method was chosen owing to its capability of measuring the value of welfare change that would accrue to a community from improving the quality of a non-marketed consumption good such as drinking water. The method is further discussed in the section below.

The rest of the paper is structured as follows: the section below presents the theoretical framework of the CV. The 'Materials and methods' section is next, followed by the 'Results' section and finally 'Conclusions'.

Theoretical framework

Most empirical studies on peoples' preferences for water quality improvement have previously been conducted using CV. The use of CV has been justified because water quality improvement is a public good, hence unpriced and with no established market for its trading (Carson & Hanemann, 2005; Gunatilake et al., 2007; Mehrara et al., 2009). The method is deeply rooted in the neo-classical welfare economic theory of consumer behaviour on expenditure minimization (Mitchell & Carson, 1989; Freeman, 1993). In the case of this study, consider the following general expenditure function for an individual living in Baringo County:

$$e\left(p,\ q,\ u\right) = y \tag{1}$$

where p is a price vector, q is the quality of drinking water in the county, u is the level of utility, and y is the minimum income that is necessary to allow the individual to maintain utility level u given prices p and level of drinking water quality, q, in the county. Furthermore, consider a situation where a water policy is proposed to improve water quality through the removal of excess fluoride from drinking water. The water policy, thus, enables all activities geared towards the removal of excess fluoride in drinking water. The individual is then asked about the amount she would be willing to pay towards the proposed water policy and thereby enhance the quality of drinking water. The expenditure function for the initial period before the proposed water policy would thus be:

$$e\left(p,\ q_0,\ u_0\right) = y_0 \tag{2}$$

where u_0 is the initial level of utility that the individual can enjoy given prices p, q_0 is the initial level of water quality before the implementation of the proposed water policy in the county and y_0 represents the minimum level of income required to attain utility level u_0. Since the proposed water policy is expected to improve water quality in the county by removing excess fluoride in drinking water, the new expenditure function would therefore be:

$$e\ (p,\ q_1,\ u_0)\ =\ y_1 \tag{3}$$

where q_1 is the quality of drinking water after the implementation of the proposed water policy and y_1 represents the minimum income level required to attain utility level u_0 after the implementation of the proposed water policy. Notably, the level of utility, u_0, is held constant since Hicksian welfare measures assume that utility remains constant. Hence, the individual's willingness to pay (WTP) for improved quality of drinking water would be a compensating variation measure since an individual would have to part with a certain dollar amount for the improvement to occur. The compensating variation (C) is equal to the individual's WTP and is given by difference between the expenditure functions y_1 and y_0:

$$C = WTP = \ y_1\ -\ y_0$$
$$= \{e\ (p,\ q_1,\ u_0)\}\ -\ \{e\ (p,\ q_0,\ u_0)\} \tag{4}$$

The quality of water in the county after the implementation of the proposed water policy, q_1, is supposedly greater than the initial quality of water, q_0. As utility and prices are held constant, y_1 (the minimum income level required to attain utility level u_0 after implementation of the proposed policy) is less than y_0. Therefore, the compensating variation would be negative meaning that an individual has to pay some dollar amount to attain the improved level of water quality.

Materials and methods

Study area

The study was conducted in Baringo County, which is located in the former Rift Valley Province, about 270 km north-west of Nairobi and covers an area of 11,015.32 sq. km. The county has two distinct weather patterns with temperatures in the southern part ranging between 25 °C during the cold months (June and July) and 30 °C during the hot months (January and February) while in the northern parts, temperatures range from 30 °C to 35 °C. The county receives between 1,000 mm and 1,500 mm of rainfall annually in the highlands and 600 mm in the lowlands. Baringo experiences two rainy seasons: March to June (long rains) and November (short rains).

For the communities living in the county, agriculture is the main economic activity where those in the highlands practise cash crop farming of coffee and cotton, although food crops such as maize and beans are also grown in the area. In the lowlands, livestock keeping, mainly cattle, goats, sheep and camels, is carried out to supplement crops farming. Kabarnet town acts as the headquarters of the county where trade of livestock and farm produce, mainly maize and beans, act as the main commercial activity.

Tourism is also a major income generating activity for the county with attractions such as Lake Baringo and Lake Bogoria drawing many domestic and foreign tourists.

Population and sample

Baringo County is home to 555,561 people (Central Bureau of Statistics (CBS), 2009), which is spread over the six constituencies, namely: Tiaty, Baringo North, Baringo Central, Baringo South, Mogotio and Eldama Ravine. To safeguard the representativeness in the problem of study over the sampling process, a simple random sampling procedure was used to select 31 respondents from five constituencies significantly affected by fluorosis (i.e., Tiaty, Baringo North, Baringo Central, Baringo South and Mogotio) to make an overall sample of 155 respondents for the entire study. This sampling procedure was chosen because it would offer all residents in the selected constituencies an equal chance of being part of the study sample.

Survey technique

The study employed personal interviews based on interviewer administered questionnaires to collect information from respondents. This method was chosen because it would enable the interviewer to motivate respondents to participate fully in the interview process, probe unclear responses and convey intricate information on the subject of study to the respondents (Arrow *et al*., 1993; Dillman, 2000). The questionnaire was divided into five sections, namely: (a) a background section that sought respondents' general knowledge on safe water in the county; (b) a section describing water fluoride removal plan to improve water quality; (c) a section describing both positive and negative effects of the water quality improvement plan; (d) a section having the valuation and the debriefing questions; and (e) a section that sought information on respondents' socio-demographic characteristics.

Survey implementation

A pre-test survey was conducted on the survey questionnaire upon 20 respondents using the open-ended value elicitation format as recommended in Haab & McConnell (2002). Respondents were asked to comment on the suitability of the questions in the questionnaire, paying close attention to wording, clarity, relevance and interpretation of each question in the survey among other anomalies. Bid ranges were also obtained from the pre-test from which the mean, median, minimum and the maximum WTP values were determined. Based on the responses and comments provided by the respondents in the exercise, a final survey questionnaire was prepared and administered to the 155 respondents.

The good valued

A water policy proposal for removing excess fluoride in drinking water in order to improve the quality of drinking water constituted the public good of interest that was valued in the study. As providing an accurate description of some definite level of water fluoride removal in drinking water may be difficult and misleading to the population, a valuation question that sought for the removal of excess fluoride in drinking water in the county was posed to respondents and the values they gave were used to estimate the mean and the median WTP values for the study sample.

Payment vehicle

Some popular payment vehicles that could be used in the study include fees, taxes and amenity bills. However, Morrison *et al.* (2000) note that some of these payment vehicles can raise objections and protest responses among the survey participants, and hence, bias the survey results. Following Fonta *et al.* (2010) and Ndambiri *et al.* (2016), this study chose to use a special trust fund, which is a neutral kind of payment vehicle, so as to minimize objections and protest responses among participants. In this fund, respondents were hypothetically required to make a one-time contribution towards the exclusive purpose of removing excess fluoride from drinking water. It was expected that the payment vehicle would enhance the credibility of the hypothetical scenario posed as opposed to other alternative payment vehicles such as fees, taxes or amenity bills often linked with protest responses in CV (Morrison *et al.*, 2000; Sayadi *et al.*, 2009).

Valuation format

The study used the PC format to elicit households' preferences based on a comprehensive water policy proposal that would remove excess fluoride from drinking water in the county. Under this format, respondents were given cards where they were asked to circle the highest amount they would be willing to pay towards the removal of excess fluoride in drinking water. Out of the responses given, inferences were made about their true WTP, which was equal to or greater than the circled value but less than the next higher value (Cameron & Huppert, 1989). This format was chosen because respondents had the advantage of easily and visually scanning through a given set of value intervals (Cameron & Huppert, 1989), and hence, determine the range within which their WTP lay. Furthermore, the kind of data obtained through this format is less scattered and, therefore, does not require larger samples to obtain robust estimates. The format does not suffer from yeah-saying and starting point bias like other CV formats (Mitchell & Carson, 1993). Although PC questions are theoretically susceptible to range and mid-point bias, there is little empirical evidence of the existence of range or mid-point bias (Klose, 1999; Ryan *et al.*, 2004). Besides, while the format still has the possibility of yielding protest zeros, it has not been found to give a very high proportion of protest zero responses compared to other CV formats (Klose, 1999; Hanley *et al.*, 2003). The valuation question was in this case formulated as follows:

> *Suppose the presented policy to remove excess fluoride in drinking water and improve water quality in Baringo County will actually be implemented to remove the current amount of excess fluoride, what is the maximum amount of money would you be willing to pay one-off into the special trust fund to achieve this? (circle or tick a single amount on the card).*

The PC included 15 different dollar amounts, namely: Kshs. 0, 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450 and finally Kshs. 500, out of which, respondents were only required to circle one single amount on the card (see Supplementary material, available with the online version of this paper).

Econometric model

Following Cameron & Huppert (1989), the interval regression model was used to estimate the mean and the median WTP values from responses generated through the PC format. Thus, letting WTP_X be the

maximum amount that a respondent would pay and WTP_Y be the lowest amount that a respondent would switch to a 'No' rather than a 'Yes' response, the individual's WTP was therefore taken to lie somewhere in the switching interval (WTP_X, WTP_Y). To adjust for the skewed distribution of WTP responses, the lognormal transformation of the WTP responses was preferred, hence:

$$Log\ WTP_i = R'_i\psi + \varepsilon_i \tag{5}$$

where R_i denotes the characteristics of the respondent or the valuation good in question, ε_i stands for the normally distributed random variable with zero mean and standard deviation σ, and ψ are regression coefficients. Assuming that WTP is a random variable (Welsh & Poe, 1998), the probability that a respondent would select a given monetary amount was:

$$Prob(yes) = prob(WTP_i \geq WTP_X) = 1 - \mathcal{M}_{WTP}(WTP_X) \tag{6}$$

where $\mathcal{M}_{WTP}(WTP_X)$ is the cumulative distribution function of the random WTP variable. The probability that the WTP would fall between any two monetary thresholds was:

$$Prob(WTP_Y > WTP_i \geq WTP_X) = \mathcal{M}_{WTP}(WTP_Y) - \mathcal{M}_{WTP}(WTP_X) \tag{7}$$

which results in the corresponding log-likelihood function for n number of respondents as:

$$Log(L) = \sum_{i=1}^{n} Log\left\{ \mathcal{M}_{WTP}\left(\frac{WTP_Y - \psi R'_i}{\sigma}\right) - \mathcal{M}_{WTP}\left(\frac{WTP_L - \psi R'_i}{\sigma}\right) \right\} \tag{8}$$

With further assumption that the stochastic term is normally distributed, ψ and σ could be estimated and then used to compute the mean and median WTP values. Thus, the mean WTP $= e^{(R'_i\psi + \sigma^2/2)}$ and median WTP $= e^{(R'_i\psi)}$. Here, R' is taken as the vector of mean values of explanatory variables, ψ as the vector of estimated coefficients and σ as the estimated standard variance.

Several diagnostic tests were also conducted prior to regression so as to determine the suitability of the regressors. They include the Spearman's correlation test conducted to assess the existence of multicollinearity among the regressors. In addition, variance inflation factors (VIFs) were also computed for further evaluation of whether multicollinearity was present among the regressors. The results of the tests are presented in the section 'Mean WTP and the determinant factors'.

Results

Socio-economic characteristics of the respondents

Table 1 presents the descriptive results of the socio-economic characteristics of the respondents. As shown, the average age of the respondents was about 39 years with men accounting for the largest share (69%) of the respondents. The share of respondents who had attained secondary level of education was 70%. Those married were 82% and the average household size was about five people. The mean

Table 1. Socio-economic characteristics of the respondents.

Variable	Description	Mean	Std dev	Min	Max	Sign
Age	Age of respondent in years (continuous)	38.74	10.39	20	70	+
Gender	Gender of respondent (dummy: 1 = male; 0 = otherwise)	0.69	0.46	0	1	+
Education	Education of respondent (categorical: 1 = no education; 2 = standard; 3 = secondary; 4 = tertiary; 5 = university)	3.51	1.09	1	5	+
Marital status	Marital status of the household head (dummy: 1 = married; 0 = otherwise)	0.82	0.39	0	1	±
Household size	Number of family members in the household (continuous)	5.19	2.45	1	15	-
Household income	Average annual earnings in Kshs. (continuous)	20,222	14,697	1,000	75,000	+
Source of income	Income source of household (dummy: 1 = farm; 0 = otherwise)	0.40	0.49	0	1	±
Living in own house	Household living in own house (dummy: 1 = yes; 0 = otherwise)	0.60	0.49	0	1	+
Type of house built	Nature of built house (dummy: 1 = permanent; 0 = otherwise)	0.65	0.48	0	1	+
Type of water source	Nature of water source (dummy: 1 = public; 0 = otherwise)	0.72	0.45	0	1	±
Perceived quality of water	Quality of drinking water (dummy: 1 = good; 0 = otherwise)	0.78	0.42	0	1	+
Proximity to market centre	Nearness to a market centre (dummy: 1 = yes; 0 = otherwise)	0.62	0.49	0	1	±
Distance to the nearest water source	Distance to the nearest water source (continuous)	0.97	2.10	0.01	12	+
Confidence with payment vehicle	Whether confident with payment vehicle (dummy: 1 = yes; 0 = otherwise)	0.59	0.49	0	1	+
Fluorosis in the household	Whether household member has suffered some form of fluorosis (dummy: 1 = yes; 0 = otherwise)	0.57	0.50	0	1	+

annual income was Kshs. 20,222 ($202.22) with about 40% of the household income being sourced from farm-related activities. The majority of respondents (60%) lived in their own house with a considerable majority (65%) saying they had built permanent houses. A majority of the households (72%) sourced drinking water from a public facility with an average location of about 0.97 km from their homes. Although a large share of respondents (78%) perceived the quality of water to be good, about 57% of the households had at least a household member suffering from some form of fluorosis. A large share of respondents (62%) resided closer to market centres, with a majority (59%) saying they were confident about the payment vehicle used in the study to hypothetically channel their contributions in support of the water policy proposal for excess fluoride removal in drinking water in the county. Therefore, the use of the special trust fund seemed to have wide acceptance among respondents in the county.

Table 2 presents the analysis of various types of WTP responses derived from the study. The survey had a total of 155 respondents. Out of this total, 129 respondents (83%) indicated a positive WTP for the removal of excess fluoride from drinking water while 26 respondents (17%) gave a zero WTP value. To separate protest responses from true zeros, a closed-ended debriefing question was presented to

Table 2. Summary of the WTP responses.

WTP responses	Frequency	Per cent
Positive WTP responses	129	83
True zero WTP responses	15	10
Analytical sample size	144	93
Protest responses	11	7
Total sample size	155	100

respondents to justify why they had a zero WTP towards the removal of excess fluoride from drinking water. Four possible alternatives were therefore presented to respondents, namely: (a) because water quality improvements have no value to me as I am satisfied with the status quo; (b) because it is the responsibility of the government; (c) because of many other basic financial commitments; and (d) because it is the responsibility of the political leaders.

Following Strazzera *et al.* (2003), the first (a) and the third (c) responses were classified as true zero values while the other two as protest responses since they did not address the value of the good in question but, some objection as to who should really pay for water quality improvements. Based on the above classification, 15 respondents (10%) therefore gave a true zero WTP value while 11 (7%) gave a protest response. In line with the standard practice in valuation studies (e.g., Wang & Whittington, 2000; Brouwer, 2009; Ndambiri *et al.*, 2016), the protest responses were dropped from the analysis. Therefore, only 144 responses, about 93% of the initial sample size, were subjected to further analysis.

Mean WTP and the determinant factors

As mentioned earlier, the Spearman's correlation test conducted to assess the existence of multicollinearity among the regressors shown in Table 3 ruled out the presence of multicollinearity since the rho coefficients of correlation were below the established rule ($r < 0.9$) for the regressors (Strazzera *et al.*, 2003). In addition, the variance inflation factors (VIFs) also justified the absence of multicollinearity among the variables since the computations yielded a mean VIF of 1.22 against a yardstick of 10.0. With these results, estimates of households WTP towards the removal of excess fluoride from drinking water were therefore evaluated and the determinant factors analysed.

As shown in Table 3, the study found that respondents were, on average, willing to pay Kshs. 202.25 ($2.02) with a median value of Kshs. 162.50 ($1.62) to remove excess fluoride from drinking water. The mean and the median welfare values of removing excess fluoride from drinking water were estimated at Kshs. 112.4 ($1.12) and Kshs. 90.3 ($0.90) million, respectively. To assess factors influencing households WTP, the grouped data on WTP were regressed against the socio-economic characteristics of the respondents, namely, age, gender, education, marital status, household size, income, source of income, whether living in own house, type of house built, type of water source, perceived water quality, proximity to a market centre, distance to the nearest water source, confidence with payment vehicle and whether a household member has had some form of fluorosis. Further results of the interval regression analysis are as shown in Table 3.

As shown in Table 3, it was expected that age of the respondent would have a positive relationship with households' WTP. This is because older people may, in one way or another, have experienced the adverse effects of excessive fluoride in drinking water and, therefore, more willing to pay for its removal than younger people. The study results, however, showed the existence of a negative relationship

Table 3. Interval regression results on factors explaining individual WTP.

Variable	Coefficient	Std. errors
Age	−0.020**	0.009
Gender	0.345*	0.187
Education	0.311***	0.083
Marital status	−0.355	0.241
Household size	−0.088**	0.037
Household income	0.223*	0.119
Source of income	0.282	0.185
Living in own house	0.382**	0.175
Type of house built	0.266	0.211
Type of water source	0.714***	0.184
Perceived quality of water	0.406*	0.210
Proximity to market centre	−0.237	0.201
Distance to the nearest water source	0.172***	0.041
Confidence with payment vehicle	0.329*	0.182
Fluorosis in the household	0.433***	0.171
Constant	3.554***	1.067
Log likelihood	− 402.313	
Number of observations	144	
LR chi^2 (15)	22.96	
Probability $>$ chi^2	0.000	
Mean WTP in Kenya shillings (US$)	202.25 (2.02)	
Standard error	12.52	
Bootstrapped 95% confidence intervals	177.78–227.25	
Median WTP in Kenya shillings (US$)	162.50 (1.62)	
Standard error	25.87	
Bootstrapped 95% confidence intervals	136.50–186.00	

*, ** and *** denote $p < 0.1$, $p < 0.05$ and $p < 0.01$.

between respondents' age and their WTP, which implies that younger people were more willing to pay for the removal of excessive fluoride from drinking water than older people. This is probably because younger people may have had the desire to undertake preventive as opposed to curative measures towards the adverse effects of drinking water with excessive fluoride early in their life and, therefore, more willing to pay than the older people.

A positive relationship between gender and the WTP was also hypothesized and the results were as expected; that is, men were more willing to pay for the removal of excess fluoride from drinking water than women. The most likely reason is that men control household budgets as opposed to women and would therefore be more willing to pay for the prosed policy than would women. The study results also revealed that education had a positive relationship with the WTP. In this case, more educated members of the population were more willing to pay for the proposed water policy than non-educated members. A negative relationship was also found between household size and WTP, which implies that households with fewer members were more willing to pay than their counterparts with more household members. This is perhaps because households with fewer members had less financial commitments as opposed to their counterparts with more household members.

Household income is another important variable used in the study to explain individuals' decisions to pay for the removal of excess fluoride from drinking water. It was expected that individuals with higher

incomes would be more willing to pay towards the proposed water policy than their counterparts with lower incomes, which would conform to economic theory (Loomis & Ekstrand, 1998). The results are positive and, hence, theoretically validate the outcome of the study. A positive relationship also emerged between living in own house and the WTP. This denotes that households living in their own houses had a higher WTP than their counterparts living in rented houses. The type of water source also had a positive influence on households WTP, suggesting that households sourcing water from a public facility had a higher WTP than those sourcing water from a private facility. This is possibly because of the perception that public water sources are unsafe for drinking. The perceived quality of drinking water also had a positive influence on the households WTP in that households were more willing to pay for improved quality of drinking water. As for the distance between the source of water and the place of residence, the study established that households dwelling further away were more willing to pay for the proposed water policy than their counterparts residing shorter distances to a water source. Households where members had suffered from some form of fluorosis had a higher WTP than households where no member had a previous incidence of fluorosis. Finally, the use of the special trust fund as a payment vehicle was found to have a positive influence on people's WTP for the removal of excess fluoride from drinking water.

Conclusions

This study analysed households' preferences for removing excess fluoride from drinking water in Baringo County, Kenya, based on responses from the CV PC format. The research was inspired by the need to estimate the welfare benefits of implementing a water quality improvement plan for Baringo County since the adverse effects of excess fluoride in drinking water were on the rise due to rapid urbanization and high population growth experienced during the last decade. The study results have shown that households in Baringo were willing to pay positive amounts towards the removal of excess fluoride from drinking water and, thereby, improve the quality of drinking water. While a few people were willing to pay true zero amounts towards the same course, citing many financial commitments within the household, a few others gave protest responses against the water quality improvement plan saying the government and/ or the political leaders should bear the responsibility of the water quality improvement plans. In monetary terms, households in the study were, on average, willing to pay Kshs. 202.25 ($2.02) for the removal of excess fluoride in drinking water. The median WTP was Kshs. 162.50, which is equivalent to $1.62. The mean and the median welfare benefits of excess fluoride removal from drinking water were estimated at Kshs. 112.4 ($1.12) and Kshs. 90.3 ($0.90) million, respectively. Moreover, age, gender, education, household size, income, living in own house, type of water source, perceived quality of water, distance to the nearest water source, payment vehicle and incidences of fluorosis within the household were found to have significant effects on households' WTP decision for the water quality improvement plans.

Since excess fluoride problems in drinking water continue to worsen in the county due to increased urbanization and high population growth, the county authorities could now use the estimated mean and median WTP to benchmark their budget and water policy proposals for the removal of excess fluoride from drinking water. Based on the study findings, these budget and policy proposals could also be adjusted for the socio-demographic characteristics of the households as they have been found to be important determinants of the households' WTP decision. The valuation estimates could also be used to determine the economic efficiency of other water quality improvement plans in the county and beyond since households' preferences are evident and determinate. Finally, more studies are necessary

to further our understanding on the welfare benefits of tackling specific health problems (e.g., dental fluorosis and/or skeletal fluorosis) that arise from drinking water with excess fluoride. Such studies may provide varied additional information to decision-makers on how to deal with different water quality problems in a developing country context.

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