

WILLINGNESS-TO-PAY FOR THE "NUPUMP" INLINE HANDPUMP CHLORINATOR IN WESTERN GHANA

John Trimmer, Joyce Kisiangani & Jessica Tribbe



With funding from Water4 and the Conrad N. Hilton Foundation, Aquaya examined willingness-to-pay for handpump chlorination amongst rural communities serviced by 4Ward Development West Africa, the Ghanaian subsidiary of Water4, an international nonprofit that starts and scales safe water businesses in Africa. The study compared two methods for estimating willingness-to-pay: the double-bound dichotomous choice method and discrete choice experiments. Both methods belong to the category of "stated preference" or reported approaches. This study was an opportunity to compare the results as well as the pros and cons of each method.

BACKGROUND

Almost half of the population (40%) in sub-Saharan Africa rely on handpumps for drinking water [1]. However, 25% - 50% of these handpumps have detectable levels of fecal indicator bacteria (e.g., *Escherichia coli*) [2-4]. Additionally, water stored in the household often has higher contamination levels because of further contamination during transport and storage [5,6].

Chlorination at the handpump inactivates microorganisms initially present in groundwater and provides a chlorine residual that reduces the risk of additional contamination during transport and storage. Water4 has developed the NuPump, an inline handpump chlorinator that relies on a solid chlorine cartridge to treat water as it gets pumped. The NuPump also includes a filter to ensure that chlorine chips coming off the cartridge or solid particles coming from groundwater, such as iron precipitates, are not present in the outflow water (Figure 1). **This study evaluated household willingness-to-pay (WTP) for the NuPump inline handpump chlorinator in rural Ghana.**



Figure 1: The NuPump – The left panel shows specifics of the NuPump; the right panel shows a NuPump installed on an India Mark II handpump.

METHODS

This study was conducted in Wassa East district (Western region of Ghana). 4Ward Development, the Ghanaian subsidiary of Water4, provides monthly handpump maintenance in 45 rural communities in Wassa East district under the NUMA franchise.¹ In 2020 and 2021, 4Ward Development installed NuPumps in 10 NUMA communities; the “treatment” communities (Table 1). We enrolled an additional 31 NUMA communities in this study as “control” communities; these did not receive the NuPump to chlorinate their water. The remaining four communities where 4Ward Development operates were used to pilot the data collection tools and were excluded from the final analysis.

We surveyed a total of 661 households: 184 within the 10 treatment communities and 477 within the 31 control communities (Figure 2). Our goal was to determine how much households were willing to pay to have their water chlorinated. We used two methods to determine WTP: the double-bound dichotomous choice method and discrete choice experiments (DCE). We applied each method to approximately 50% of the study population. Data collection took place in August-September 2021.

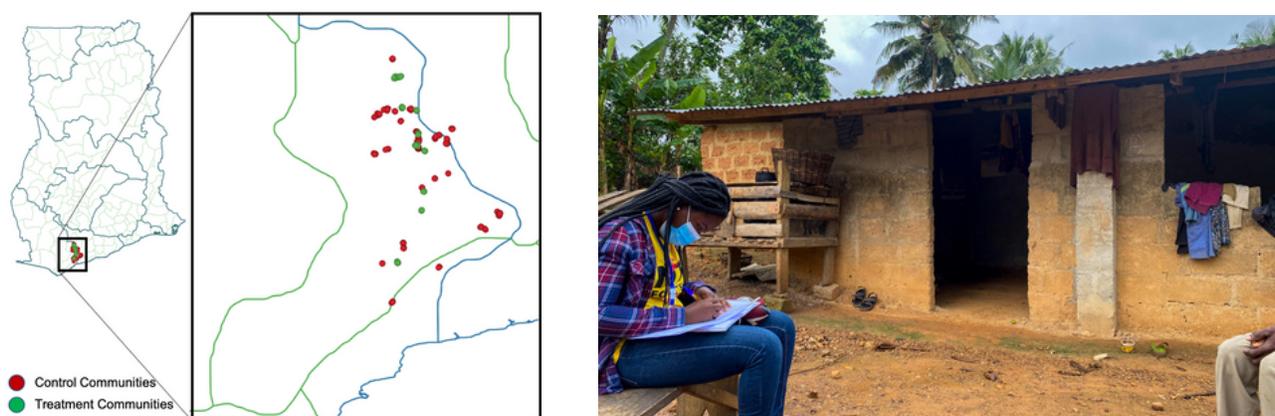


Figure 2: The left panel shows a map of the study communities within the study district (Wassa East, Western Region of Ghana); the right panel shows a field enumerator conducting the willingness-to-pay survey.

Double-bound dichotomous choice

The double-bound dichotomous choice method consisted in a series of three questions. First, the respondent was asked if he/she would be willing to pay an extra amount X to have the chlorination device on the community handpump. If the answer was yes, the same question was asked about an extra amount Y higher than X (or lower if the first answer was no). Finally, the respondent was asked about the maximum amount that he/she would be willing to pay. Although open-ended, the third question was guided (and bound) by the first two answers. The first amount X was randomly selected from 1 / 2 / 4 / 6 Ghana Cedis (GHS) (1 USD = ~ 6 GHS in September 2021).²

Discrete choice experiments

Discrete choice experiments (DCE) consisted of a series of questions, called “choice sets”, asking the respondent’s preference between the following options:

1. **Option A:** Handpump maintenance only (i.e., NUMA only) at amount X per month.
2. **Option B:** Handpump maintenance combined with chlorination (i.e., NUMA + NuPump) at amount Y per month.
3. **Option C:** None, that is, paying 0 GHS per month and not using the handpump.
4. **Option D:** Don’t know (when respondents cannot afford options A or B but the handpump is their only possible source of water).

¹ Overall, 4Ward supplies 91.5% of the population in Wassa East with NUMA water through a mix of modular piped water networks and handpumps. NUMA is Water4’s branded franchise model currently being provided in four countries- Ghana, Sierra Leone, Zambia, and Uganda.

² Source: Google, consulted on January 3, 2022.

Respondents were presented with four “choice sets” (i.e., four questions such as the one described above), where amounts were randomly selected from a list of 13 pairs.³ An example of a choice set question is: “Imagine a situation where you had to choose between these two options: handpump maintenance at 7 GHS per month or handpump maintenance and chlorination at 10 GHS per month, which one would you pick?” Enumerators initially read out options A and B, and only presented options C and D when the respondent stated that he/she could not afford options A or B. To triangulate responses, enumerators also asked about the respondent’s maximum WTP.

We then analyzed respondents’ preferences using a mixed (random parameters) logit model, which produced a distribution of individual WTP based on statistical assumptions. Within this model, we controlled for household wealth, current payments for the NUMA program, and whether the household was in the treatment or control group.



Image 1. Chlorinator installation in Wassa East district, Ghana.

Table 1. Summary of control and treatment groups.

Group	Description	Number of Communities	Number of surveys	Timing of survey	Timing of NuPump installation	Time from installation to survey
<i>Control</i>	NUMA handpump with regular maintenance	31	477	Aug-Sep 2021	-	-
<i>Treatment</i>	NUMA handpump with regular maintenance and NuPump chlorinator installed	10	184	Sept 2021	Aug 2021*	23-37 days

* Five treatment communities had previous exposure to an earlier version of the NuPump chlorinator, which had been installed and operated during 2020, for approximately 11 months.

FINDINGS

CURRENT PAYMENTS FOR THE NUMA PROGRAM

The communities in our study area were small, with an average of 16 households. Across all communities, most households (69%) reported contributing 2 GHS per month for the NUMA program (Figure 3), which provides regular handpump maintenance services. The mean payment was 1.9 GHS (Figure 3). Accordingly, an average community with 16 households would be paying approximately 30 GHS per month for maintenance of the handpump.

Although most households reported paying 2 GHS per month, several (22%) reported not currently contributing any amount to help pay for the NUMA program. A few others reported paying more to ensure that the program continued despite these non-paying households. In one extreme case, a single household reported paying 40 GHS per month, because that household was the only one regularly using the NUMA handpump in the community. To increase adherence to household

³ Choice set pairs: 2-4 GHS; 2-7 GHS; 2-10 GHS; 4-2 GHS; 4-7 GHS; 4-10 GHS; 7-2 GHS; 7-4 GHS; 7-10 GHS; 10-2 GHS; 10-4 GHS; 10-7 GHS; 4-4 GHS.

payments, some handpump caretakers (~40%) reported not allowing households that had not paid their monthly subscription to fetch water. Despite the variability in household contributions, all study

communities were fulfilling their contractual payments to 4Ward at the time of our data collection, a requirement for the enterprise to continue providing handpump maintenance.

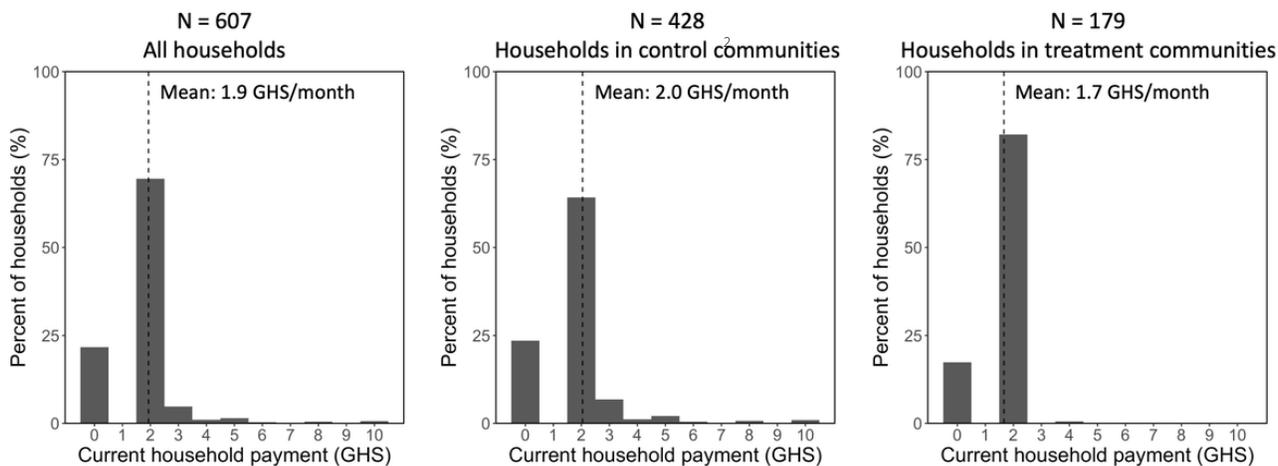


Figure 3. Distributions of existing household payments into the NUMA program for handpump maintenance among all households, those in control communities, and those in treatment communities (where NuPump chlorinators had been installed).

FINDINGS

HOUSEHOLD WILLINGNESS-TO-PAY FOR CHLORINATION

According to the double-bound dichotomous choice method

With the double-bound method, we found that 82% of households would be willing to pay at least 1 GHS in addition to their current NUMA contribution (Figure 4). The average household was willing to pay approximately 2 GHS for chlorination, essentially doubling their existing NUMA payment. However, WTP declined considerably above this level of 2 GHS; for example, only 13% of respondents were willing to pay 4 GHS on top of their current payment (Figure 4).

Households in treatment communities tended to exhibit lower WTP for chlorination than those in control communities ($p=0.02$). On average, WTP in treatment communities (where the NuPump chlorinator was already installed) was 0.6 GHS less than in control communities when accounting for other factors also influencing WTP (including wealth, respondent gender, and whether the household used the NUMA handpump as their

primary water source). Interviews with community members and handpump caretakers suggested that households in control communities may have expected the installation of the chlorinator to solve all existing issues with their handpumps, while the experiences of households in treatment communities showed that the NuPump could introduce additional challenges while not addressing all existing concerns. Specifically, households in treatment communities noticed that the NuPump reduced the handpump's flow rate and some did not like the smell of chlorine coming from the water. Additionally, community members had hoped that the NuPump chlorinator would solve issues related to the water's aesthetic quality (e.g., a salty taste), but these challenges persisted after installation, causing these households to realize that the chlorinator cannot address some key concerns.

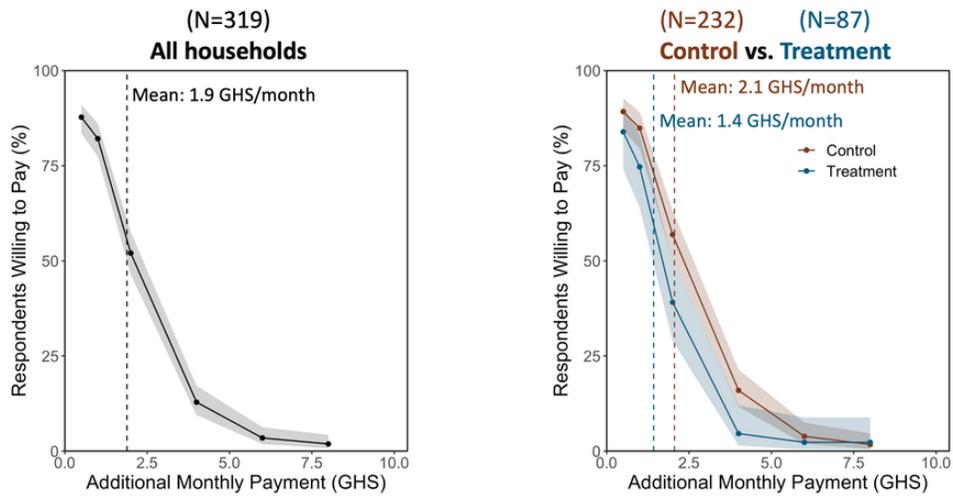


Figure 4. Willingness-to-pay curves for handpump chlorination using NuPump, based on the double-bound dichotomous choice method. Mean willingness-to-pay in treatment communities was 0.7 GHS lower compared to control communities (or 0.6 GHS lower when controlling for wealth, gender, and primary water source).

According to discrete choice experiments

On average, WTP for handpump chlorination estimated with the DCE method was 2.2 GHS per month, quite similar to the estimate obtained from the double-bound method (1.9 GHS/month). However, the DCE method estimated that only 66% of households would be willing to pay at least 1 GHS per month (compared with 82% with the double-bound method). The DCE method also

identified that treatment households exhibited lower WTP than control households ($p < 0.001$), and the estimated difference between the two groups (1.6 GHS per month less among treatment households) was more pronounced than what was found through the double-bound method, reinforcing the idea that households in treatment and control groups have different conceptions of the benefits and drawbacks of the NuPump chlorinator.

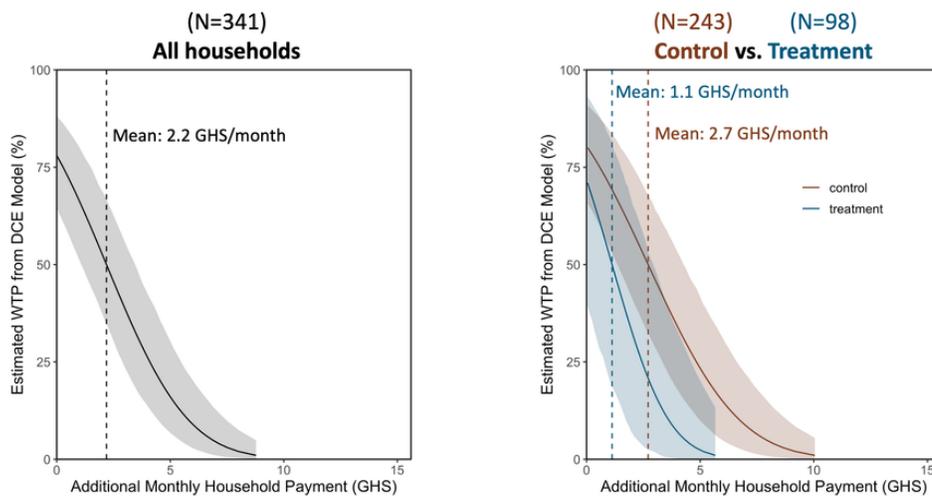


Figure 5. Willingness-to-pay curves for handpump chlorination using NuPump, based on the discrete choice experiment (DCE) method. The models shown here controlled for confounding factors (including a household's wealth and current payments to the NUMA program).

DISCUSSION

COMPARING WTP METHODOLOGIES

Generally, the results generated from the two WTP methodologies (double-bound and DCE) were quite similar (Figure 6), suggesting that these results are likely to be robust and reliable, at least at the time of the survey. Both methods estimated that **households would be willing to pay an average of approximately 2 GHS per month for the installation and operation of the NuPump chlorinator on the community handpump** (Figure 6). However, this average represents an amount that only about half of households would be willing to pay (the median was also close to 2 GHS), and both methods also indicated that WTP likely decreases once communities have been exposed to handpump chlorination and have a greater understanding of what issues it can and cannot address. **A lower price point of approximately 1 GHS per month would thus be more appropriate.**

However, the methods themselves have some important differences and may be more suitable in different situations (Figure 6). First, the double-bound method relies on respondents' stated WTP and the resulting curve directly reflects their responses. In contrast, the DCE method estimates the WTP curve using statistical modeling techniques, which rely on assumptions about the overall shape of the distribution (e.g., normal, log-normal, uniform) and what confounding factors to include [7,8]. Accordingly, while both methods produced equivalent estimates of mean WTP, **the double-bound method may provide a more reliable picture of the full WTP distribution.**

However, the DCE method has several advantages:

1. Because DCE allows respondents to make relative comparisons and select preferred options, it requires of them an easier task than directly reporting the maximum price they would be willing to pay, especially for unfamiliar products (such as the NuPump chlorinator in control communities of this study) [8].

2. The models used to estimate WTP in the DCE method enable direct consideration of the effects of distinct product features, meaning that they can

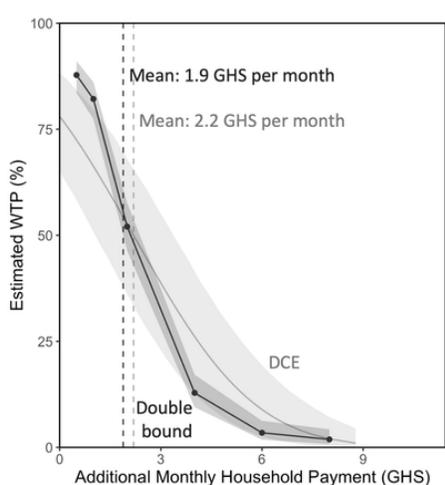
directly assess tradeoffs associated with different attributes of a product. Our study of the NuPump chlorinator involved a relatively simple comparison between options with only one distinct attribute (whether or not the chlorinator was installed), but product scenarios can be much more complex and incorporate several attributes. **This ability to compare attributes is often cited as one of the main advantages of the DCE method [9].**

3. DCE statistical models can account for confounding factors that may have an impact on a respondent's WTP (e.g., wealth). In contrast, the double-bound method does not account for confounding factors when estimating WTP, though tools such as regression analysis can separately evaluate possible relationships between WTP and other factors.

4. The double-bound method may be vulnerable to anchoring [10], where a respondent's maximum reported WTP can be influenced by the previous price points that were presented (e.g., higher price points may lead respondents to report a higher maximum WTP).



Image 2. An enumerator conducting a willingness-to-pay survey in rural Ghana.



Consideration	Double-bound dichotomous choice	Discrete choice experiments
WTP distribution	WTP distribution is the direct reflection of respondents' answers	Estimates WTP distribution using statistical assumptions and models
Estimating the effects of specific features and other confounding factors	Cannot directly account for the impacts of specific factors, but regression analysis can identify associations	The effects of multiple features and other factors can be accounted for directly in the statistical model when estimating WTP
Difficulty of response	May be difficult for respondents to state exact WTP for a single item without a basis for comparison	Allows respondents to easily compare between 2 choices and select the preferred option
True reflection of willingness to pay	Does not force respondents into a choice that may be higher than true WTP	Respondents may feel forced into a choice and report what they would be able to afford if forced, which may be higher than true WTP
Anchoring	Price points used in the survey questions can affect ("anchor") a respondent's maximum WTP	Less vulnerable to anchoring
True reflection of actual behavior	Stated Preference methods risk overestimating true WTP	Stated Preference methods risk overestimating true WTP

Figure 6. Comparison of the WTP distributions for handpump chlorination produced by the two methodologies, as well as their strengths (blue) and weaknesses (orange).

Finally, we observed that respondents in our study sometimes felt that the DCE method was forcing them to choose between two options with price points that were too high. We did include an “opt-out” option, in which respondents could state that they would not pay and would not use the handpump. However, some respondents who lived in communities with no or limited alternative water sources did not see opting out as a realistic option, because it would mean going without water. These households may thus have reported the amount that they were *able* to pay (i.e., that they could afford if forced to), though this may have been higher than the amount that they were truly *willing* to pay (if given a real choice). The fact that water is a basic necessity may mean that *ability* to pay is sometimes higher than *willingness* to pay, and the DCE method may measure the former rather than the latter. It is also important to note that both approaches (DCE and double-bound) are classified as *Stated Preference* methods; they rely on hypothetical scenarios that do not involve actual purchases, and therefore they may overestimate true willingness-to-pay [8].

The suitability of each individual method will likely depend on the complexity of the product and the goals of the study. **Especially if the product is**

relatively complex, or if the study objectives include understanding how distinct attributes or other external factors relate to WTP, we would likely recommend the DCE method.

Generally, it provides a simpler task for respondents to perform and offers robust modeling options to consider distinct product attributes and external factors when estimating WTP (although, formulation of the models themselves can be somewhat complex). However, caution may be warranted when using the DCE method with products that provide basic necessities. If there are no viable alternatives for meeting this need, respondents may not see opting out as a realistic choice, and they may feel forced into choosing an option with a price that is higher than what they would truly be willing to pay. In such a scenario, it is advisable to include consistency checks to flag responses that could overestimate WTP. **Alternatively, if the study objectives are particularly concerned with defining a detailed distribution of individual WTP for a relatively simple product with no variation in attributes, then the double-bound method may be more appropriate.** However, the analysis should include tests to determine whether anchoring may have influenced the results.



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Design: Vanessa Guenther