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## Article

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# Willingness to pay (WTP) for arsenic-safe drinking water: A case study to understand societal embedding of ECAR technology in rural West Bengal, India

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## ABSTRACT

This paper analyzes users' willingness to pay (WTP) for safe drinking water in a resource-poor region in West Bengal, India, with dangerously high groundwater arsenic concentrations. The study was carried out during the installation of an Electro Chemical Arsenic Remediation (ECAR) water treatment plant at the site. Using a contingent valuation method, the study elicits WTP, based on a stratified random sample of 1003 households. Arsenic is invisible and odorless, and related health risks have a prolonged latency period. As a result, awareness about arsenic and the perceived benefits of any arsenic remediation technology are low. In the study area, only 21% of respondents were aware of the danger of high arsenic concentrations in groundwater, however, a large number of the respondents reported irregularity of drinking water supply and a lack of quality assurance. About 64% of the respondents were willing to pay for ECAR-treated safe drinking water. Participants opting for home delivery were willing to pay more than those willing to collect water from the plant. The average WTP was high enough to recover the operational cost of the plant. Households with higher income and educational attainment, more awareness about arsenic contamination, and living in proximity to the plant were willing to pay more than the others. Regular interaction with the community, maintaining transparency, and interacting closely with the local administration created a sense of local ownership for the technology that was found to be crucial for the societal embedding of the technology.

## 1. Introduction

Lack of access to safe drinking water is one of the daunting development challenges that the world faces today. One out of every four individuals does not have access to safe drinking water in their homes (UNICEF, 2021). Among several pollutants causing contamination of drinking water and hence creating public health hazards, elevated level of arsenic in groundwater is a major one that affects millions of people worldwide (Podgorski and Berg, 2020). It remains a silent killer since neither is the presence of arsenic detected by human senses nor is the testing of the level of arsenic always included in the regular water quality tests. Epidemiological studies have documented several symptoms that are manifested post-long-term exposure to arsenic. These include arsenical skin manifestation, deposition in arsenic in hair, nail,

urine, etc. (Nriagu et al., 2007). Long-term ingestion also leads to skin cancer, diabetes, pulmonary and cardiovascular diseases, resulting in loss of productivity, and higher rates of morbidity and mortality (WHO, 2018). The current statistics of the World Health Organization suggests that at least 140 million people in 50 countries are consuming drinking water with a highly elevated level of arsenic (WHO, 2018), and the presence of this toxic chemical is regularly being detected in new locations (Podgorski and Berg, 2020; Nordstrom, 2002; Brammer and Ravenscroft, 2009 and the references therein). Parts of several countries in the Asian continent, such as India (Basu et al., 2015; Nickson et al., 2000, 2007; Chatterjee et al., 1995), Bangladesh (Karim, 2000; Nickson et al., 2000), China (Rodriguez-Lado et al., 2013), Pakistan (Ali et al., 2019), Vietnam (Berg et al., 2001), Japan (Nriagu et al., 2007)), Iran (Hamidian et al., 2019); in Europe, such as England (Ayotte et al., 2006),

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Greece (Kouras et al., 2007); and in the Americas, such as Argentina, Mexico (Armenita and Segovia, 2008; Armenita et al., 2012; Camacho et al., 2011), and the USA (Welch et al., 1998, 2005; Camacho et al., 2011) are detected to have high levels of arsenic concentration in the groundwater.

The Ganga-Brahmaputra-Meghna basin, comprising of parts of India and Bangladesh, is one of the areas worst hit by this problem with millions of people being exposed to the risk of arsenic contamination (Biswas et al., 2021; Hernandez et al., 2019; Bhowmick et al., 2018; Delaire et al., 2017; Das et al., 2016; Murcott, 2012; Roy, 2008; Chakraborti et al., 2003). The district of North 24 Parganas in West Bengal, India was the first place where an elevated level of arsenic (more than 50 µg/L, the then permissible national limit) was detected in groundwater (Chakraborty et al., 2015). The modeled probability of arsenic concentration in groundwater exceeding the permissible limit of 10 µg/L for this area in the future was also found to be very high (Podgorski and Berg, 2020). Historically, easy availability, microbial safety, and the absence of sufficient infrastructure for both treatment and distribution of surface water led to extensive use of groundwater for drinking in this region (Sarkar et al., 2010). This not only led to a public health hazard but also increased the social vulnerability of the resource-poor people in the region (Biswas et al., 2021).

While technological solutions for groundwater arsenic remediation do exist, in most cases they are either expensive or technically complicated or both to be adopted by a community, especially in the resource poor regions of South Asia (Hernandez et al., 2019). Studies revealed that in several affected districts of rural West Bengal, India, ~95% of arsenic remediation technology became dysfunctional within a year of installation (Das et al., 2016). Similar failures are also documented in neighboring countries - Bangladesh (Kabir and Howard, 2007) and Nepal (Gebauer and Saul, 2014). Post-failure analysis suggests that the reasons include lack of sustainable business models, lack of understanding of the existing user-practices, lack of societal readiness for technology adoption leading to a low willingness to pay (WTP)<sup>1</sup> (Hernandez et al., 2019; Das and Roy, 2013; Kabir and Howard, 2007; GOI, 2007, 2010; Gebauer and Saul, 2014). The existing technology-centric view that the solution can be achieved only through appropriate design and installation of technology, therefore, needs to be revisited.

The concept of 'societal embedding' of technology provides a useful framework in this context. 'Societal embedding' implies the acceptance of technology by the community and stakeholders. It is shaped by the enthusiasm about the benefits of the technology and concerns about potential risks (Geels et al., 2007; Williams and Edge, 1996). Since arsenic is invisible and odorless, and the associated health risks are not always immediate, consumers and policymakers with their present-biased time preferences, often undervalue the benefits of arsenic remediation (Ahmad et al., 2003; Gebauer and Saul, 2014; Roy, 2008). At the same time, there are always concerns about the risks related to an unknown technology, especially for a community-scale treatment plant with no centralized institutional system in place. Given this, when a new safe-water technology is implemented, the community must emerge as an important stakeholder, and also the WTP for the service generated by the new technology becomes comparable with the cost of provisioning safe drinking water.

The present study was carried out in a rural location of India, where a community-scale Electro Chemical Arsenic Remediation (ECAR) technology was installed as a part of a demonstration project. As opposed to an aid-based/subsidy-based model, a participatory and market-based approach was planned to be adopted, where a socially valuable good/service was being distributed against a payment (Gebauer and Saul, 2014). Previous studies showed that this makes people more confident,

proud, instills a sense of ownership, and they become powerful stakeholders in the process (Viswanathan et al., 2009). However, the sustainability of a market-based business model to provide a socially valuable good/service is largely determined by the preferences and readiness of the consumer. This readiness is shaped by the perception of safe drinking water, the need for provisioning, perceived benefits from provisioning, WTP, and affordability (Vasquez et al., 2009; Gadgil, 1998). A lack of information on consumers' preference regarding potential improvement in the water supply system, in general, has remained an impediment to the provisioning of safe drinking water in various parts of the world (Gadgil, 1998). Even if there is an unmet 'need' for safe drinking water, it does not translate to 'demand' if potential beneficiaries are not willing and/or able to pay a price higher than the total costs to the seller.

Against this backdrop, the present study aims to explore the existing drinking water user practices in the study area, the WTP for ECAR-treated safe drinking water, and societal readiness towards the technology adoption. It also documents the need for social science research, in addition to engineering design, for the societal embedding of ECAR. The remaining parts of the paper are divided into four sections. Section 2 describes the study site, Section 3 demonstrates the methodology, Section 4 provides results and discussion, and concluding remarks are presented in Section 5.

## 2. The ECAR technology and the study site

ECAR was invented and patented by Gadgil Lab at the University of California, Berkeley and Lawrence Berkeley National Lab, USA. It is an iron-based electro-coagulation technology with a demonstrated efficiency to reduce arsenic levels from >500 µg/l to <10 µg/l (Amrose, 2010). Previous field trials of ECAR conducted in India and Bangladesh yielded consistent performance and the technology was suitable for a community-scale micro-utility business model (Hernandez et al., 2019; Amrose et al., 2013, 2014). The demonstration project, which is relevant for this study, commenced in 2014 and aimed to implement and commercialize a 10,000 L per day (LPD) prototype of ECAR. This was the first large-scale demonstration of ECAR in the field. The components of the treatment plant under the demonstration project were fabricated by selected Indian manufacturing companies. The process of knowledge transfer, including the learning and unpacking of engineering design of ECAR in India, was led by a multidisciplinary research team at Global Change Programme, Jadavpur University, Kolkata, India in collaboration with the Gadgil lab.

The site for the 10,000 LPD-ECAR demonstration plant was set up at Dhapdhapi High School in Baruipur administrative block, District 24 Parganas (South) of West Bengal, India. To select the final site for ECAR within the Baruipur administrative block, a criteria matrix was developed. It included arsenic concentration levels in the groundwater, the potential availability of space for plant installation, existing infrastructure in the location, source of water supply, cooperation from stakeholders, the number of potential beneficiaries, and the distance from the nearest city, Kolkata. Among all criteria, the highest weight was assigned to arsenic concentration in groundwater. Based on the criteria matrix, Dhapdhapi High School was finally selected as the study site for the demonstration project. Arsenic concentration in groundwater in the school premise was found to be 200–250 µg/l across samples. The number of direct beneficiaries in the school was estimated to be ~3000, which included students, teachers, and other staff members of the school. If the plant ran at full capacity, it could cater to 5000 people assuming an average drinking water demand of 2 LPD per person. Therefore, the starting hypothesis was even if the school community was provided water free of cost to compensate for their in-kind contribution and operational costs, there would still be surplus treated water. This could then be sold to nearby communities against a price, and the revenue could support the maintenance of the plant beyond the project duration. Thus, a socio-economic study to understand societal readiness

<sup>1</sup> Willingness to pay is the maximum price/monetary value that a person is willing to pay for a good or service from which he/she derives utility or to avoid consumption of good or services that causes negative utility.

was carried out in the main catchment area of Dhapdhapi High School, i. e., in 16 villages of Dhapdhapi I and II Gram Panchayats (GP), which are the village level administrative units in India.

The location not only had a high arsenic concentration in ground-water but also a living memory of significant investment in arsenic remediation technology and its subsequent failure. In 2001, a Technology Park Project was set up at Baruipur by the All-India Institute of Hygiene and Public Health, Kolkata, in collaboration with several non-governmental organizations (NGOs) and with the financial support of the India-Canada Environment Facility, New Delhi. The objective was to demonstrate, monitor, and evaluate available arsenic remediation technologies (SOFR, 2003). Arsenic safe water was delivered to the local community for drinking and cooking immediately after the Technology Park was set up. However, within a few years, other than 2–3 technologies, the rest in the Technology Park were found to be either non-functional or ineffective to deliver arsenic-safe drinking water (Hossain et al., 2005, 2006).

### 3. Methodology

A primary survey was carried out to understand societal embedding challenges of ECAR and WTP was estimated for ECAR-treated arsenic-safe drinking water, based on contingent valuation method (CVM). During the period of commissioning, a range of stakeholders was interviewed at regular intervals with structured questionnaires along with unstructured consultations and focused group discussions. A total of 1003 households were surveyed in Dhapdhapi I and Dhapdhapi II GPs based on stratified random sampling. Each of the 32 polling booths<sup>2</sup> in these two GPs was one stratum. The survey was conducted by approximately 20 enumerators during the month of May–November 2015 with subsequent visits for clarification and cross-checking through 2016 when the plant was being commissioned. The interview was conducted only for those respondents who provided informed verbal consent.

#### 3.1. Survey instrument

The questionnaire had four sections. The first two sections dealt with the demographic and socio-economic characteristics, the third section dealt with the sources of drinking water and water for other uses. The final section had the CVM-based survey to elicit WTP. Before the survey, the draft questionnaire was developed and tested through two rounds of pilot surveys, followed by required modifications. The survey was conducted by enumerators who were specially trained to carry out CVM surveys, and the interviews on the field were supervised by project team members. The final questionnaire was digitized using Open Data Kit and was installed in individual tablets to facilitate data collection directly in a digitized format to minimize human errors and to increase time efficiency.

#### 3.2. Value elicitation through CVM

CVM-based surveys are designed to elicit respondents' preferences for a good/service that does not have a well-defined market and is contingent upon a hypothetical scenario and description of the said good/service. The preference that the respondents elicit is referred to as 'stated preference' (Ahmad et al., 2003), and can be treated as the basis for the demand curve for the good/service. Here, a brief discussion is provided on what WTP implies given the relevant economic theory of consumer behavior and how CVM can be administered to elicit WTP in the absence of a market. The CVM-based WTP study was designed to

assess the Hicks compensated demand curve (Gravelle and Rees, 2004) for ECAR-treated safe drinking water. The Hicks compensated demand curve is derived in such a manner that the indirect utility of the consumer remains the same whether he/she chooses to pay for water or not. This implies that the reduction in utility for making a payment towards safe drinking water must be compensated by gains in utility from improved quality and access to water services. Therefore, it is important to remind the respondents that they were operating under an income constraint and if they chose to purchase ECAR-treated safe drinking water they had to sacrifice some other consumption.

Following the model specification of Vasquez et al. (2009), the indirect utility function of household  $i$  in the sample can be assumed as:

$$V_i = V(M_i, P, W, Z_i) \quad (1)$$

where,  $M_i$  is the income level of household  $i$ ,  $P$  is the price index of other goods and services,  $W$  is the set of attributes associated with drinking water supply system and  $Z_i$  is the set of relevant characteristics of household  $i$  (e.g., education, distance from ECAR treatment plant, etc.).  $V$  is an increasing function of the level of income ( $M_i$ ) and improvement in the state of drinking water provisioning ( $W$ ) and a decreasing function of a price index ( $P$ ). Thus, household  $i$ 's maximum WTP, i.e., ( $WTP_i$ ) for provisioning of safe drinking water leading to a change in  $W$  from the status quo  $W_0$  to an improved situation  $W_1$  can be captured by equation (2) where the indirect utility remains unchanged:

$$V_i = V(M_i, P, W_0, Z_i) = V((M_i - WTP_i), P, W_1, Z_i) \quad (2)$$

The purpose of a CVM study is to elicit  $WTP_i$  through a stated preference method.

##### 3.2.1. Addressing biases in CVM

To obtain reliable data by controlling for potential biases under CVM depends on the appropriate design of the questionnaire and the quality of administering the survey. For value elicitation under CVM, both the close-ended referendum type method and open-ended elicitation method were followed in this study. In the referendum question, the respondents were asked whether they were willing to purchase ECAR-treated safe drinking water or not. Since CVM-based WTP surveys encounter several issues related to validity and measurement (Venkatachalam, 2004), a triple bounded dichotomous choice experiment (Langford et al., 1996) was carried out to collect information on preferences of the households towards improved water quality. This is the close-ended elicitation method where the first dichotomous choice question was followed by another two sets of dichotomous choice questions depending on the previous answer. It increases the efficiency of the CVM and is effective to reduce both hypothetical bias (respondent indicating more than what he/she would pay) and strategic bias (respondent wanting a particular price to prevail and the response is guided by that objective) (Vasquez et al., 2009). It can also provide a better understanding of the distribution of the response as compared to a single bounded dichotomous choice. Close-ended dichotomous choices, however, often suffer from a 'starting point bias' or a 'yea-saying bias' (Venkatachalam, 2004). To minimize such biases and to provide both lower and upper valuation boundary estimates, an open-ended question was also asked: "What is the maximum amount you are willing to pay per liter of ECAR-treated arsenic-safe drinking water?"

Hypothetical bias was addressed through 'honesty and realism' approaches and 'cheap talk' (Loomis, 2014). Respondents were repeatedly requested to report what they would honestly pay, here and now, and their response should not be guided by what they think the price of it is going to be. They were also informed that similar studies in the past showed a tendency to overstate the WTP and they should restrain themselves from that. To curb scenario misspecification bias, before asking a WTP question, the respondents were carefully informed about the problem of arsenic contamination, related health effects, social impacts, cost of treatment, alternative sources of safe drinking water, and

<sup>2</sup> Polling booths are public voting locations during general political elections in the country. Very well-organized official records are available on each household at this administrative level of disaggregation within the village administrative stratification.

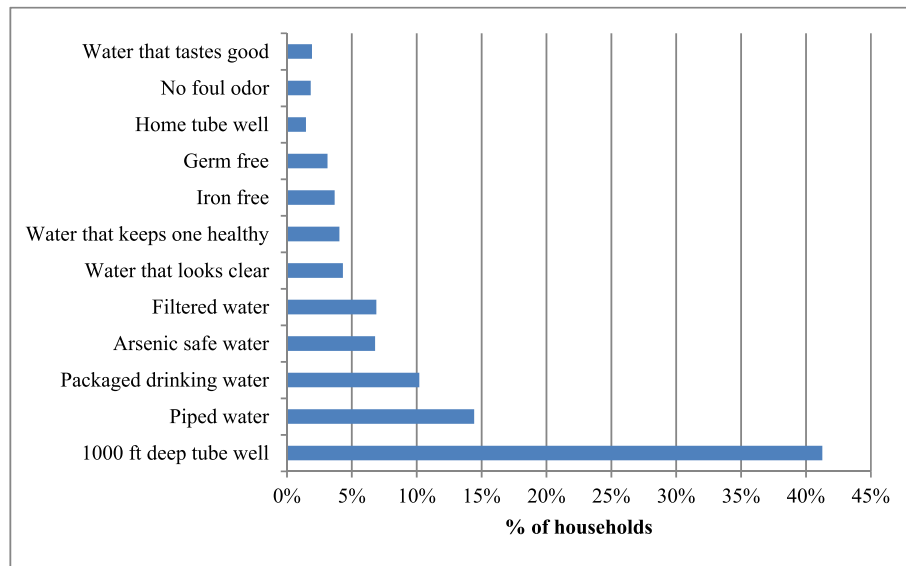


Fig. 1. Perception of safe drinking water.

the features of ECAR treated water.

### 3.2.2. Testing construct validity of CVM

To ensure the construct validity of the study design, two things were checked: 1) whether the law of demand holds, i.e., whether the number of respondents who are willing to pay declines as the magnitude of WTP rises; and 2) econometric models are used to regress WTP on several socio-economic variables to understand the important determinants of WTP and to ascertain the validity. First, a logistic regression model<sup>3</sup> is used to identify the factors that increase the probability of being willing to pay (Model 1 and 2 in Table 3), and then Ordinary Least Square (OLS) regressions (Maddala and Lahiri, 2012) are used to identify the significant determinant of the magnitude of the highest WTP (Model 3 and 4 in Table 3). While in the case of the logistic regression the dependent variable is based on the response to the referendum question and is binary, in OLS, the dependent variable is the maximum WTP stated in response to the open-ended question and is, therefore, a continuous variable. This section provides a brief discussion of the regression models estimated in the study.

Logistic regression: In response to the referendum question the households stated whether they are willing to pay or not. Let  $y_i$  be a binary variable such that:

$$y_i = 1, \text{ if the household is willing to pay} = 0 \text{ otherwise.}$$

$y_i$  can be conceptualized as a realization of a random variable  $Y_i$  that can take the value 1 and 0 with probabilities  $p_i$  and  $1 - p_i$ , respectively.  $p_i$  depends on a vector of observed variables, i.e., a set of explanatory variables (household characteristics, distance from the plant location, etc.). One may estimate a linear probability model to obtain the estimated value of  $p_i = x_i'\beta$ , where  $x_i$  is the vector of these explanatory variables and  $\beta$  is a vector of regression coefficients. However, there is a difficulty with the estimation of such linear probability models. While the actual value of the dependent variable  $p_i$  should range between 0 and 1, the predicted value of  $p_i$  can go beyond this range given the fact that  $x_i'\beta$  can assume any real value. One simple solution is to transform  $p_i$  to its odds ratio  $\frac{p_i}{1-p_i}$  and consider the logit function:  $\text{logit}(p_i) = \ln\left(\frac{p_i}{1-p_i}\right)$ . Since the logit can assume any real value, it can be regressed on  $x_i'\beta$  such

that:

$$\text{logit}(p_i) = x_i'\beta + e_i \quad \forall i \quad (3)$$

where,  $e_i$  is the error that may follow a normal or a logistic distribution. Since the sample size is fairly large in this study, it will not be expected to render much difference whether the errors are assumed to be normally or logistically distributed.

$$\text{Also, } \text{logit}(p_i) = \ln\left(\frac{p_i}{1-p_i}\right) = x_i'\beta + e_i \quad \forall i \quad (4)$$

$$\text{i.e., estimated value of } p_i = \frac{\exp(\text{logit}(p_i))}{1 + \exp(\text{logit}(p_i))} = \frac{\exp(x_i'\beta)}{1 + \exp(x_i'\beta)} \quad \forall i \quad (5)$$

It also implies that the estimated odds for  $i$ th observation is given by  $\exp(x_i'\beta)$ .

$\beta_j$  represents the change in the logit of the probability associated with a unit change in the  $j$ th explanatory variable holding other variables constant. These coefficients are interpreted as the marginal effects of the change in the respective explanatory variable on  $p_i$ . The derivative of  $p_i$  with respect to  $j$ th explanatory variable is given by:

$$\frac{\partial p_i}{\partial x_{ij}} = p_i(1 - p_i)\beta_j \quad (6)$$

Thus, the effect of  $j$ th explanatory variable on the probability to be willing to pay depends on  $\beta_j$  and the value of probability itself. In the present study, these  $\beta$  coefficients are estimated through the maximization of the log-likelihood function of  $\beta$  using STATA 14. STATA output includes the values of log-likelihood functions as it iterates to its maximum. A detailed discussion on logistic regression and use of Maximum Likelihood estimation using referendum data can be found in (Kmenta, 1997) and (Cameron, 1988).

Ordinary Least Square (OLS) regression: Following the logistic regression, OLS regressions are run with the same set of explanatory variables and with a natural log of maximum WTP as the dependent variable.

The OLS regression model is specified as:

$$\ln WTP_i = x_i'\beta + e_i \quad \forall i \quad \text{where } e_i \sim iid(0, \sigma^2)$$

In this model, the dependent variable is the stated maximum WTP in response to the open-ended question.  $\beta_j$  in this model represents the change in the magnitude of the maximum WTP due to a change in the  $j$ th

<sup>3</sup> A logistic regression model estimates a logit function that is a log of odds in favour of an event i.e.  $\text{logit}(a) = \ln\left(\frac{a}{1-a}\right)$ .



**Table 1**  
Knowledge about water borne and arsenic related disease.

Awareness type	Yes	No	Do not know	Total
Regarding water borne diseases	885	118	0	1003
About Arsenic	569	434	0	1003
About Arsenic related diseases	480	89	0	569
Future risk perceived (from arsenic related diseases)	214	168	98	480

explanatory variable. The goodness of fit of the model is reported in terms of adjusted R square. The OLS regressions are also run using STATA 14. A detailed discussion on OLS regression can be found in (Kmenta, 1997) and (Maddala and Lahiri, 2012).

#### 4. Results and discussion

In this section, along with the results of the WTP analysis, we also discuss the perception of the community about safe drinking water, knowledge about arsenic, and their perceived need for safe drinking water. These are factors likely to affect the WTP of the consumers.

##### 4.1. Perception of safe drinking water and knowledge about arsenic

In response to the open-ended question “*What do you understand by safe drinking water?*”, a range of answers was obtained (Fig. 1). Households mostly associate the concept of “*safety*” with a particular “*source*”. 67% of sample households mentioned a particular source such as “*deep-tube well in location x*” in response to this question while only 14% talked about explicit properties of safe drinking water such as arsenic safety, germ-freeness, iron-freeness, etc. Another 8% talked about the taste, odor, and clarity.

There are two major existing public sources for drinking water in the study area: groundwater lifted through a 1000 ft deep tube-well attached with a hand pump and intermittent surface water supplied through the pipeline by the Public Health and Engineering Department. As per official records, piped water in the area is to be supplied against a monthly rental of INR 30 (< USD 0.5) but due to lack of enforcement hardly anybody was reported to be paying during our survey. Other than these, some private arrangements for water purification are also there

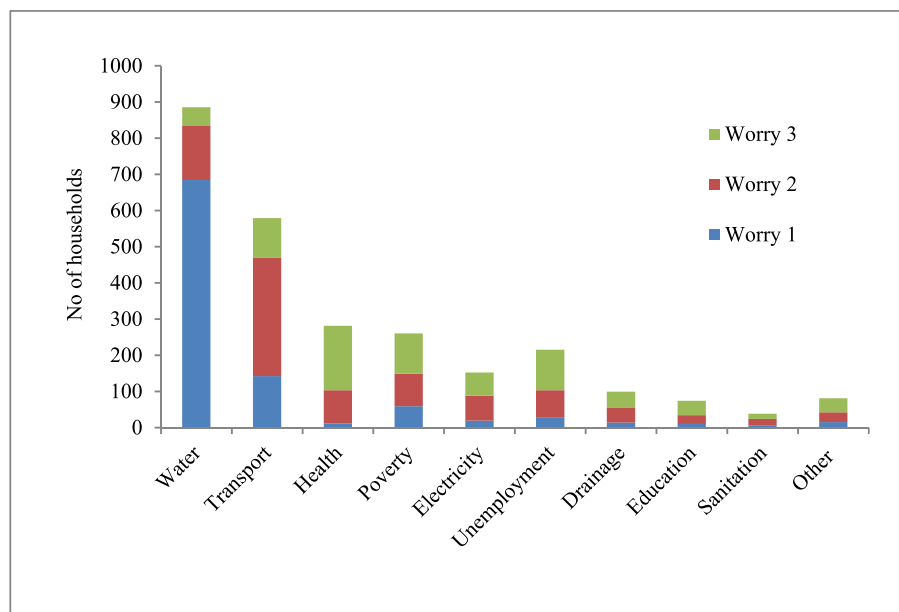
but the quality of water sold under such arrangements remained untested. People occasionally collected water from privately installed shallow tube wells within their premises, from ponds, or bought bottled drinking water.

Out of the 67% households associated water safety with sources, 41% thought that the water they get from a 1000 ft deep tube-well was what one can call “*safe drinking water*” while another 14% thought that the piped water supplied by PHED was safe. 11% of respondents considered packaged drinking water to be the safest option. In a subsequent question, respondents were requested to state their ordinal preference for a 1000 ft deep tube well, piped water, and packaged drinking water for consumption, under the condition that each of the options can be availed by spending no/same amount of money and time. When controlled for monetary resources and time, packaged drinking water emerged as the most preferred option with 46% of households opting for it. It is important to note that this analysis was done merely to understand the perception of households and has no implication towards the actual safety standards of the sources.

Although Baruipur block is one of the most severely arsenic-contaminated areas in West Bengal, not everyone in the study area was aware of what arsenic contamination is and/or what the related threats are. Only 74 out of 1003 (7%) respondents spontaneously, without a lead from investigators, related the general safety of drinking water with arsenic safety (Fig. 1). However, when asked directly, 57% (569 out of 1003) respondents mentioned that they had heard about arsenic contamination (Table 1). Many of the respondents confused high levels of iron concentration in the water (leaving brown patches in the container) as arsenic contamination. Only 48% of the surveyed households knew about arsenic-related diseases and 21% perceived future health risks from it. Respondents were more familiar with the visible symptoms like the pigmentation of skin, diarrhea, and bruising as the effects of arsenic and were less aware of the severe carcinogenic impact.

##### 4.2. Perceived need for provisioning of safe drinking water

Although the perception of safe drinking water varied among surveyed households, the lack of availability of safe drinking water in the area was a major concern. To understand whether the community considered the provisioning of safe drinking water to be one of the major challenges in their day-to-day lives, the respondents were asked the open-ended question (without a lead): “*What are the three most important*



**Fig. 2.** Worry in the locality.

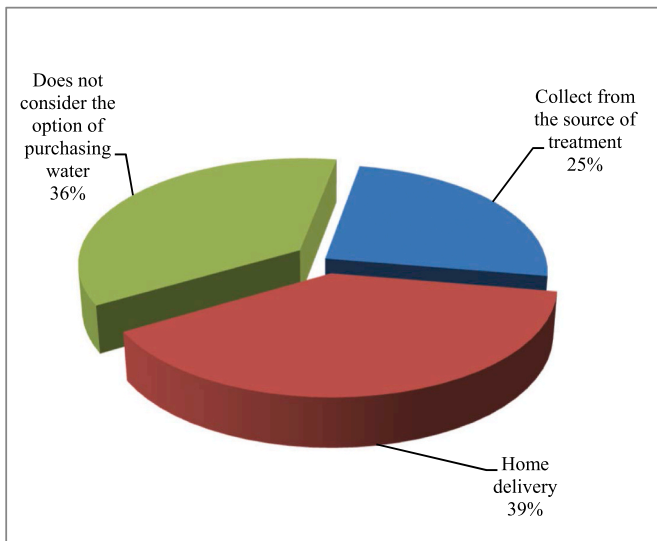


Fig. 3. Response to the referendum question.

local issues that you are worried about?“. The matter of highest concern was identified as ‘worry 1’ and the least as ‘worry 3’ (Fig. 2). Lack of availability of safe drinking water was perceived as the major worry by most of the respondents. However, this does not necessarily mean that the concern is due to arsenic contamination. They talked about several issues such as lack of sources of drinking water, insufficient and intermittent supply, poor quality of water, social conflicts during water collection from public sources due to over-crowding, etc. Many of the respondents were “captive users” of a particular source rather than a “choice user” - they mentioned that they collected water from a particular source, not because of choice but because that was the only source available within a considerable distance.

#### 4.3. Are households willing to pay for ECAR treated arsenic safe drinking water?

The WTP survey began with the referendum question to understand whether the respondent was willing to purchase ECAR-treated safe drinking water. In response, 640 out of 1003 respondents were found to

be willing to purchase ECAR-treated safe drinking water (Fig. 3). This 64% of households can be divided into two groups, based on their preferred mode of service delivery – 30% of the households preferred home delivery against an extra payment, and 25% preferred collection of water from the water treatment site. Further analysis showed that 86% of the 363 households, who did not consider the option of purchasing ECAR-treated water, were located outside the 2 km radius of the project site. Therefore, among potential non-buyers in the sample, only 14% resided within a 2 km radius of the project site (Fig. 4). This is an important observation; proximity to the project site might have created higher awareness and acquaintance among these respondents leading to this kind of a result. Many respondents mentioned that their family members participated in public meetings conducted at the school by the research team where their voices were heard during question-answer sessions and that their children were enrolled in the same school. So, a feeling of inclusiveness was found to be one of the most important parameters for the societal embedding of ECAR. Findings also suggest that the proportion of higher-income groups was greater in the case of those who preferred home delivery (Fig. 5). For those who did not consider the purchase option, over 80% had per capita monthly income less than INR. 2000 (~30 USD), indicating inadequate affordability. Whether these variables are significant determinants of the WTP were analyzed based on regression results.

#### 4.4. How much are they willing to pay?

A triple bounded dichotomous choice experiment was undertaken to elicit the WTP for ECAR-treated safe drinking water. The starting price of the dichotomous choice was 75 paisa per liter of treated water if delivered to home or 50 paisa per liter collected from the treatment plant. If a household is willing to pay 50 paisa per liter then it implies that the increase in utility due to consumption of safe drinking water is not less than the utility foregone in terms of reduced consumption of other goods/services worth 50 paisa. The starting prices were quoted based on the estimated cost of provisioning safe drinking water through ECAR. In subsequent rounds, the prices were halved for respondents who were not willing to pay the quoted amount and doubled for those who were willing to pay. The prices quoted in the subsequent rounds and corresponding responses are summarized in Fig. 6. Based on this response, the mean WTP for those who were willing to collect from the plant location and those who preferred home delivery were found to be

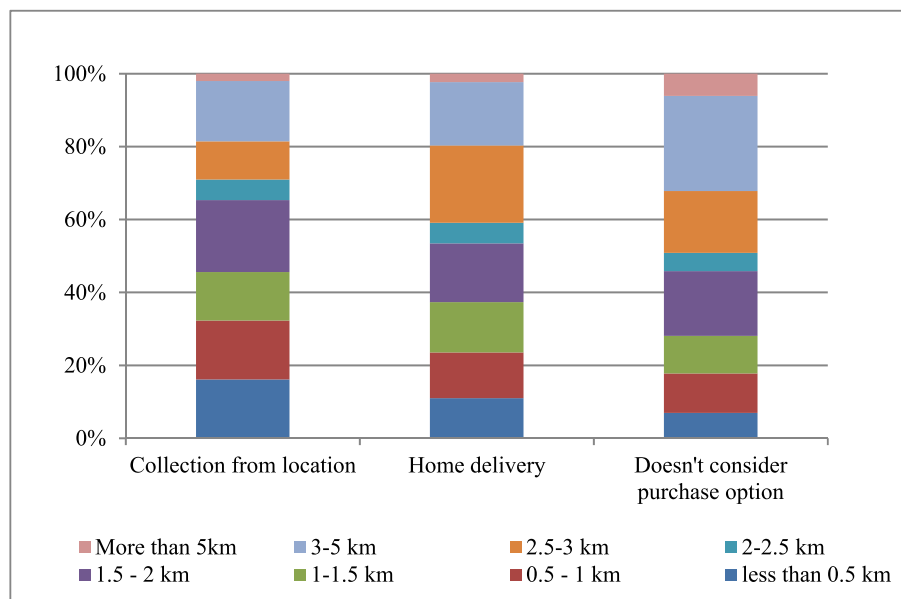


Fig. 4. Relationship between distance from Dhaphdapi High School and preference of purchase and mode of collection.

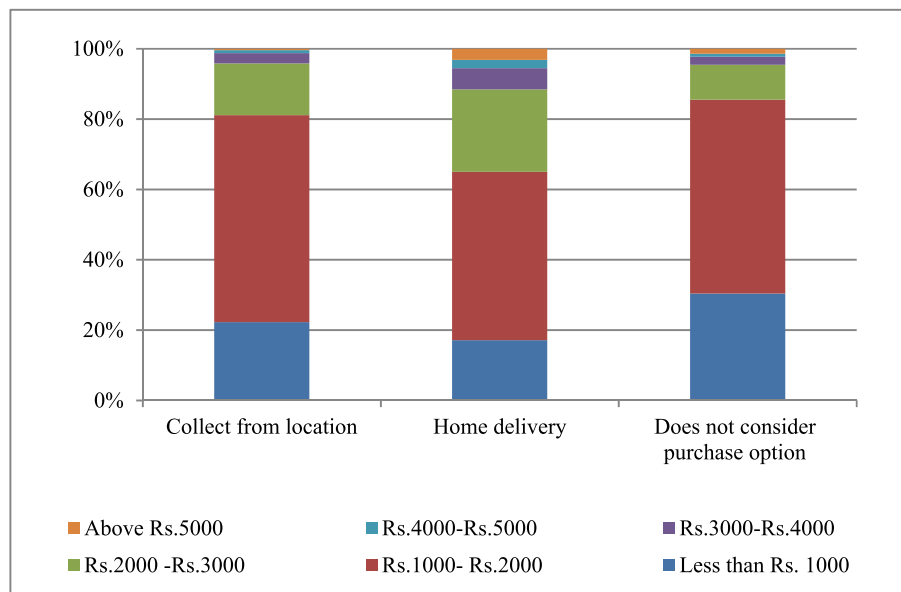


Fig. 5. Relationship between expenditure category and preference regarding purchase and mode of collection.

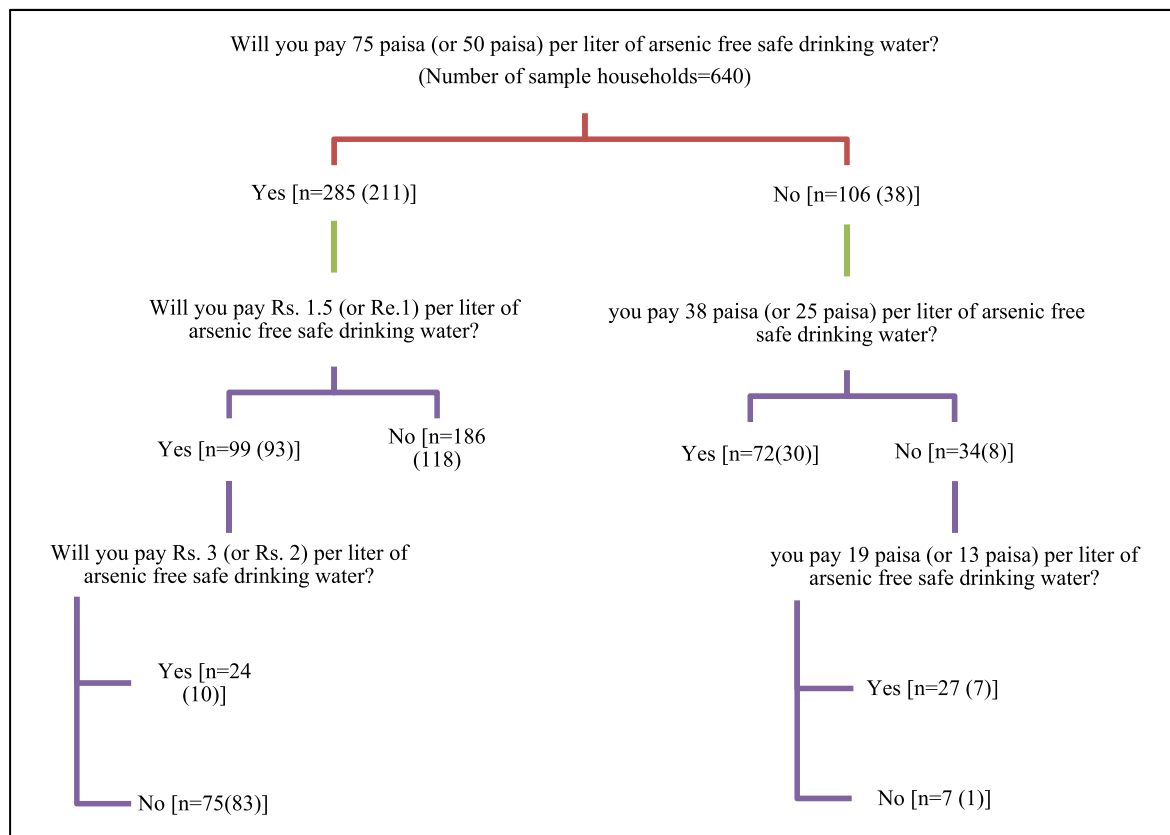


Fig. 6. The design of the dichotomous choice.

Rs. 0.68 and Rs. 0.92, respectively. The median WTPs for these groups were Rs. 0.5 and Rs. 0.75, respectively.

The responses from the open-ended question regarding the highest WTP are represented in Figs. 7 and 8. Each bar represents the number of households with stated WTP greater than the corresponding amount in the vertical axis. This provides an idea about the shape of the demand curve. The fitted lines in both diagrams show that, on average, there is a negative relationship between price and demand, and that supports the

basic law of demand. As mentioned in Section 4.2.2, this is an important aspect of the construct validity/theoretical validity of the CVM study. Figs. 7 and 8 show that there is a sharp fall in demand when the price is raised from 50 paisa per liter to 1 Rupee per liter for the group who preferred to collect water from the site. A similar decrease in demand can be observed for the other group when the price is increased from 75 paisa per liter to Rs. 1.50 per liter. The demand is relatively inelastic for the price range below 50 paisa per liter (or 75 paisa per liter).



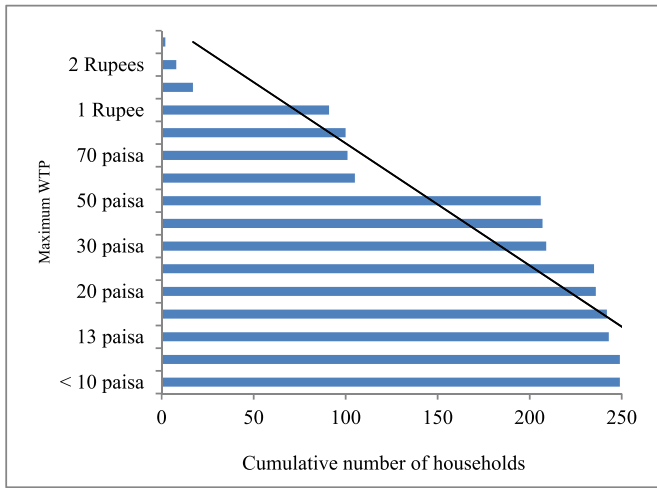


Fig. 7. Demand pattern of those who prefer to collect water under open ended WTP.

#### 4.5. Analyzing WTP and its determinants

##### 4.5.1. The explanatory variables

The explanatory variables for the logit model (Equation (5)) and OLS model (Equation 7) are chosen based on literature and the observations made during the focused group discussions and field trials of the questionnaire. Previous studies found economic, social (institutional trust and social norms), aesthetic factors, and knowledge about arsenic as important determinants of demand for safe drinking water (Delaire et al., 2017; Polyzou et al., 2011; Ahmad et al., 2003) (WHO/UNICEF, 2006). The explanatory variables included in this study are broadly economic (monthly per capita expenditure), demographic (age and gender), level of education, geographical proximity to the water treatment plant, and knowledge about arsenic contamination. Table 2 explains the variables and the motivation behind their inclusion along with descriptive statistics.

##### 4.5.2. Determinants of WTP

Model 1 in Table 3 represents the results of the logit model (based on Equation (5)) where the dependent variable is binary indicating whether the respondent is willing to pay for safe drinking water or not. The explanatory variables are mentioned in Table 2. The odds ratios of each of the variables along with the Wald z values are reported. An odds ratio significantly higher than 1 implies that the increase in the value of the explanatory variable significantly increases the probability of having a positive WTP. The model has a high LR (likelihood-ratio) Chi-square value suggesting that it performs better than a constant-only model. In Models 2 and 3, the dependent variable is the natural log of the maximum WTP. While Model 2 is run for those who preferred collecting water from the ECAR treatment plant, Model 3 is for those who preferred home delivery. Both Model 2 and 3 have low adjusted  $R^2$ . However, a low  $R^2$  in the case of estimation of behavioral models is not uncommon given the difficulty in specifying the functional forms (Vasquez et al., 2009).

The coefficient of the explanatory variable MPCE is positive and significant in Model 1 while the LNMPCE is also positive and significant in Models 2 and 3. This shows that households with a higher monthly per capita expenditure are more likely to pay for arsenic-safe drinking water. Since expenditure and income are positively correlated, this also implies that high-income families are more likely to have higher WTPs. Also, Models 2 and 3 suggest that the maximum amount that a household is willing to pay increases with income. This finding is important to establish the construct/theoretical validity of the model. This implies that households perceive the quality of water (especially arsenic safety) as a normal good/service. In Model 1, age is found to be significant at a 10% level of significance indicating that respondents from an older age group are relatively less likely to be willing to pay as compared to their younger counterparts. However, the same variable is not found to be significant in any other model. The time spent by the household to collect water does not seem to affect significantly the decision of whether to pay for safe drinking water or not as the variable is not significant in Model 1. However, those who prefer to collect water from the plant are willing to pay more if they are currently spending more time collecting drinking water. Whether the respondent is the main water collector of the household, and the gender of the respondent are not found to be significant in explaining the WTP - these variables are

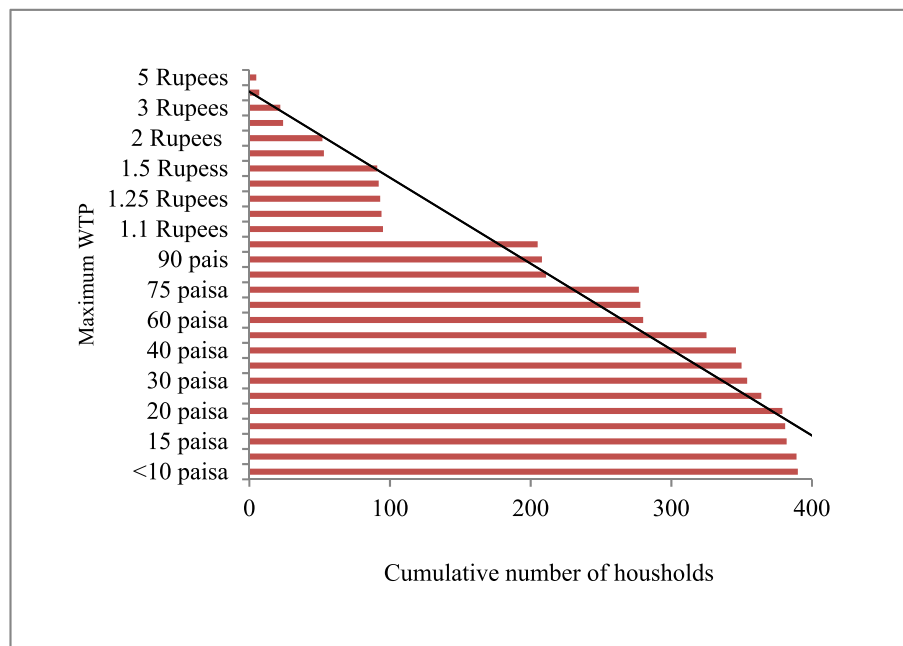


Fig. 8. Demand pattern of those who prefer home delivery under open ended WTP.

**Table 2**  
Variables and descriptive statistics.

Variable	Description	Hypothesis to be tested	Mean	Standard Deviation
WTP	= 1, if the respondent is willing to pay for safe drinking water, 0 otherwise (Dependent variable in the logit model)	NA	NA	
LNWTP	Natural log of maximum WTP (Dependent variable in OLS model)	NA	0.69	0.72
MPCE (LNMPCE)	Monthly per capita expenditure (in Rupees) (Natural log of monthly per capita expenditure): Since there was some resistance in revealing monthly income by the households, monthly expenditure is taken into account to proxy the purchasing power of the household. The correlation coefficient between monthly income and expenditure for those who reported both income and expenditure are found to be 0.847.	$\beta_{MPCE} > 0$	6584	4801
AGE	Age of the respondent (in years): The motivation is to understand whether younger generation is more prone to purchase safe drinking water as compared to the elderly. This was triggered as during the group discussions previous to the survey researchers came across situations with conflicting opinions from the older and younger participants regarding this. In some cases while the older respondents were not willing to pay for safe drinking water as they believed that provisioning of safe drinking water should be available free of cost, the younger family members strongly opposed.	$\beta_{AGE} < 0$	39.89	15.25
GENDER	Gender of the respondent [= 1, if female, 0 otherwise]. While the main purchasing power remained concentrated in the hands of male members of the family in a typical household, the gender variable is expected to capture whether such authority influences the decision to pay for safe drinking water.	$\beta_{GENDER} < 0$	.45	0.50
TIME	Time spent on water collection per day (in hours): During the group discussions and field trials, the respondents often reported that they had to travel far or stand in the queues for long given supply inadequacy of drinking water in the locality. Therefore, total time that the household spends on collecting drinking water is added as an explanatory variable in the model.	$\beta_{TIME} > 0$	0.78	0.58
KNOW_W_DISEASE	Knowledge about water borne diseases (=1, if knows about water borne diseases; 0 otherwise): Greater awareness about the consequences of drinking unsafe water may increase the WTP.	$\beta_{KNOW\_W\_DISEASE} > 0$	0.88	0.32
KNOW_As	Knowledge about arsenic contamination (=1, if knows about As; 0 otherwise): Similarly, greater awareness about arsenic contamination may increase the probability of being willing to pay for safe drinking water, especially where the focus is on arsenic safety.	$\beta_{KNOW\_As} > 0$	0.57	0.5
EDU1, EDU2 and EDU 3	Level of education (Three dummies are used to capture the level of education): EDU1 = 1, if completed class 8 as highest education, 0 otherwise; EDU2 = 1 if completed class 12 as highest education, 0 otherwise; EDU3 = 1 if studied beyond class 12, 0 otherwise. Literature suggests that increased level of social capital, especially the level of education is a significant determinant of WTP for goods and services with the characteristics of a public good.	$\beta_{EDU1} > 0$ $\beta_{EDU2} > 0$ $\beta_{EDU3} > 0$	NA	
DISTANCE	Distance from the project site (in km): It was revealed during the group discussion and the field trials that many of the households residing at a distance from the project site did not have much of information about it. However, those residing in the vicinity of the project site were mostly well aware about the ECAR treatment plant and often visited the school to have a look at the plant, asked several questions about the operation and effectiveness of the process.	$\beta_{DISTANCE} < 0$	2.4	1.6
COLLECTOR	Whether the respondent is the main water collector or not (=1, if the respondent is the main water collector for the family, 0 otherwise): This variable has been included to see whether being the main water collector who faces direct consequences of spending more time on water collection, standing in long queues, carrying water from long distance or facing certain social conflicts explain the WTP for safe drinking water.	$\beta_{COLLECTOR} > 0$	.68	0.47

not significant in any of the models.

While knowledge about water-borne diseases is significant only in Model 3, at a 10% level of significance, knowledge about arsenic is significant across models. Knowledge about arsenic contamination not only increases the likelihood of purchasing arsenic safe drinking water but those who are aware of arsenic contamination are willing to pay more as compared to those who are ignorant about the same. This implies that those who know about arsenic and related health burden attach higher utility value to arsenic-safe drinking water. However, since arsenic is tasteless, colorless, and odorless and the health impacts are realized mostly over the long term, the perceived benefit from arsenic remediation technology is likely to be underestimated. This, along with the lack of awareness about arsenic in the area, implies that there is a chance that WTPs are understated.

Education plays an interesting role. While education up to grade 12 increases the likelihood to be willing to pay (Model 1), it is not significant in determining the magnitude of the highest WTP. This is reflected in the fact that both EDU1 and EDU2 are significant at a 1% level of significance in Model 1 while they are not significant in Models 2 and 3. None of the education-related variables are significant determinants of the highest WTP of the group that is willing to collect water from the location. However, EDU3 is significant at a 5% level of significance in Model 3, implying that those who prefer home delivery are willing to

pay more if they have attained higher levels of education. Another important variable is the proximity of the house to the water treatment plant. Not only the likelihood to be willing to pay is higher for the households that are nearer to the plant site, but also the maximum amount these households are willing to pay is relatively higher. This is rather expected since the location of the project site was inside a school premises and when regular discussion sessions and awareness programmes were held by the research team, those who resided close to the school attended more frequently. Also, they witnessed the day-to-day development and operation of the plant. As a result, the nearby community felt gradually included in project design and commissioning and developed a sense of ownership. The school also acted as a bridge between the local households, facilitating public institutions and the community at large, and the research group.

## 5. Summary and conclusion

The study demonstrates the importance of exploring the ability and willingness of the consumers to purchase a service provided by new technology and investigates several local factors that shape the WTP of consumers. Apart from arsenic contamination, the community in the study area faced many challenges related to collection and quality of drinking water, including malfunctioning of and over-burden on deep

**Table 3**

What explains the WTP for safe drinking water?

Variables	Model 1 (Dependent var: WTP)			Model 2 (Dependent var: LNWTP) For those who want to collect from the location		Model 3 (Dependent var: LNWTP) For those who prefer home delivery	
	Coeff.	Odds ratio	Wald z	Coeff.	t stat	Coeff.	t stat
MPCE	0.0003	1.003***	3.19				
LNMPCE				0.142**	2.21	0.223***	3.16
AGE	−0.01	0.99*	−1.79	−0.003*	1.65	0.0001	0.03
GENDER	−0.25	0.78	−1.58	0.055	0.97	0.088	1.01
TIME	−0.09	0.92	−0.68	0.098**	2.00	−0.061	−0.85
KNOW_W_DISEASE	0.20	1.22	0.86	−0.034	−0.30	−0.229*	−1.66
KNOW_As	0.51	1.66***	3.15	0.178***	2.90	0.308***	3.23
EDU 1	0.46	1.59***	2.36	−0.014	−0.18	0.190	1.48
EDU 2	1.08	2.94***	3.8	0.032	0.33	0.201	1.35
EDU 3	0.45	1.57	1.37	−0.083	−0.70	0.418**	2.45
DISTANCE	−0.20	0.82***	−4.35	0.033*	1.91	−0.058**	−2.02
COLLECTOR	−0.08	0.93	−0.45	−0.026	−0.44	0.032	0.38
Constant	0.31	1.36	0.7	−0.409	−0.87	−0.682	−1.26
No of observation	936			227		366	
Log-likelihood	−558.258			–		–	
LR Chi-square	113.6			–		–	
Adjusted R <sup>2</sup>	–			0.130		0.103	

Note: \*\*\*, \*\* and \* imply significance at 1%, 5% and 10% levels respectively.

tube-wells, non-payment of rental charges and resultant lack of maintenance of piped water supply, lack of an accountable mechanism for quality check of available packaged drinking water, etc.

The study reveals that the perceived benefit of an arsenic remediation technology is likely to be underestimated given the lack of awareness about arsenic, and therefore, it is important that the social anxieties related to the technology must be minimized. A feeling of participation, inclusiveness, and transparency created through regular communication are important interventions to reduce perceived risk. Those who lived in the proximity of the treatment plant witnessed the process of commissioning, participated more frequently in knowledge dissemination workshops, asked questions, expressed their anxieties, received responses from the research team, and finally emerged as powerful stakeholders with a sense of ownership. These stakeholders subsequently stated higher WTPs for arsenic-safe drinking water. The school model, where the plant is installed within a school premise through collaborations, worked efficiently as the school became instrumental to maintain the connection between the research team and the community. The primary survey carried out during the commissioning of the plant also helped in alleviating misgivings about the present operations and future functioning of the plant.

The results of the study re-emphasize the role of community involvement in the social embedding of a technology. Similar results are also found in studies conducted in countries such as Bangladesh (Ashan, et al., 2021; Dey et al., 2019) and Mexico (Villarreal et al., 2018) where community involvement was found to be one of the most important determinants of WTP as well as the willingness to accept the technological intervention for provisioning of safe drinking water. All these suggest that investment in improving the drinking water system becomes a no-regret and economically sustainable decision when the benefit of such technology is admitted by the community. The ECAR demonstration plant was envisioned to have a sustainable business model to remain operational beyond the project lifetime. Results from the WTP survey showed that the majority of the respondents in the catchment area were willing to pay for safe water; some were even willing to pay a higher amount for home delivery. It revealed an indicative price range that was crucial to confirm that the cost of production could be matched with the purchasing power of the community. Based on the WTP survey and operational costs, the price was fixed at Rs. 0.60/liter for collection from the location and Rs. 0.65/liter for home delivery.

The experience from the ECAR trial clearly shows that appropriate

site selection, communication, engagement with the local community and understanding the demand pattern are important factors that can enhance societal embedding of a technology. These social innovation components are as important as engineering design innovations and are essential for societal embedding, especially in places with a memory of technology failures. However, special effort is needed to create trust and sustainable demand for arsenic safe water through a price mechanism, repeated science communication, and transparent information-sharing on water safety aspects among consumers.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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