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Adoption of Piped Water Source in an Arsenic Affected Area

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Abstract: The paper studies adoption of piped water source as mitigation strategy against arsenic contamination in an arsenic affected village of West Bengal, India. It finds that the households affected by arsenicosis are more likely to adopt an arsenic-safe source than the unaffected households. The paper also analyses the role of factors like the extensiveness of arsenicosis, intensity of symptoms and the years of experience about the health and social hazards associated with it at the household level on the adoption decision of the households. It finds that although the marginal impact of these factors on the adoption decision is small, the effect of years of suffering is stronger than the other two factors. The results derived in the paper have important policy implications. The results suggest that greater adoption of piped water sources in arsenic affected villages can be facilitated if the awareness is spread through the households, who suffered from arsenicosis for a long time. The piped water sources must be located more evenly in the clustered villages for greater adoption. A more continuous supply of piped water may remove the observed high-income bias from adoption of piped water in arsenic affected villages, where it is freely provided.

Keywords: Arsenicosis, Arsenic-safe Water Source, Mitigation, Adoption

1. Introduction

Although the adoption of piped water sources as a response to microbial contamination has been studied in details in the existing literature, not much is known about the adoption of it as a response to arsenic contamination (Amrose, Burt and Ray [15]). The present paper attempts to fill the gap.

Groundwater Arsenic contamination in the Ganga-Meghna-Brahmaputra (GMB) plain of India and Bangladesh and its consequences on human health have been reported as one of the World's biggest natural groundwater calamities to the mankind. More than 500 million people of the GMB plain may be potentially at risk from groundwater arsenic contamination [6, 22]. In India, seven states namely - West Bengal, Jharkhand, Bihar, Uttar Pradesh, Assam, Manipur and Chattisgarh have so far been reported as affected by arsenic contamination in groundwater much above the World Health Organisation (WHO) permissible limit of 10µg/Litre (Mandal et al. [20]). People in these states have chronically been affected by arsenic poisoning directly due to consumption of arsenic contaminated hand-tube-wells water and indirectly through the food chain since arsenic contaminated groundwater is used in agricultural productions. Arsenic related health hazards may be classified into two types: (i) Acute: include bone marrow depression, gastrointestinal discomfort, vomiting, diarrhoea, convulsions, coma and ultimately death (Acute toxicity however is quite infrequent) and (ii) Chronic: include skin lesions (arsenicosis or arsenical dermatitis), which are characterized by keratosis (hardening of skin), melanosis, hyper-pigmentation (dark spots like rain drops), hyperkeratosis and hypo-pigmentation (white spots)[1]. The arsenic affected individuals, due to their illness, are not only in a disadvantageous position at the labour market, their households are also socially discriminated against. They are often dismissed from their jobs. The arsenic affected children are sometimes restrained from their schools. The affected girls are refused and rejected of marriage and often married women face problems in their marital life and even divorce ensues. Affected people are quite often ignored and avoided from social functions. The arsenic affected persons are

1 See papers such as [16] and [7].

often prohibited socially as they are mistakenly considered as the patients infected with contagious diseases. The labour market and non-labour market costs of the arsenic affected households turn out to be substantial, estimated in papers such as [17, 27, 19, 8]. Therefore, it is imperative that the rational households in the arsenic affected areas would adopt the arsenic-safe sources of water as mitigation strategy. But, the arsenic-affected areas in India also being the areas affected with wide-spread microbial contamination, it is not clear whether the adoption decision is guided by arsenic contamination or microbial contamination (Delaire et al. [17]). However, it is more likely that the households respond to the microbial contamination only, as it has immediate perceptible health outcome, which the arsenic contamination does not have since it takes nearly seven years to show up its symptoms. Among the available alternative safe water sources, treated piped water adoption seems to be the best strategy against both types of contamination mentioned above[2]. The provision of piped water being costly as it is network dependent, in developing countries like India, the government in recent times has arranged for free-access, intermittent-supply of piped water at some locations at the arsenic affected villages lived mainly by the poor. Our paper studies the adoption of this source of safe-water among arsenic affected and unaffected households in an arsenic affected village of West Bengal, India.

Although we cannot be sure about motivation of arsenic-unaffected households whether they have adopted piped water as a response against microbial contamination or arsenic contamination in water, it can safely be hypothesized that the households which have already suffered from more severe incidence of arsenicosis would adopt piped water sources with higher probability. Apart from the behavioural trait and bounded rationality, their adoption decision can also be affected by the costs of adoption and economic-demographic characteristics like education, religion, percentage of female at the household and the household income. This paper takes all these costs and socio-economic factors into account and empirically seeks answer to the following research question: do the households with more severe incidence of arsenicosis show higher probability of adopting arsenic-safe water sources? It investigates the question by using a primary-survey data collected from village Kolsur (block Deganga) in the district North 24-Parganas (West Bengal, India), one of the severely affected areas, during 2015-16, and finds an affirmative answer to the question.

Among the strategies for fighting the arsenic menace, the use of arsenic-safe water sources like treated dugwell, arsenic-safe deep-tubewells (often coloured green for easy identification while unsafe are coloured red), treated piped water etc. and improvement of nutritional status are considered as the most important strategies[3]. The spread of awareness complements such strategies. Since dugwells and tubewells are more vulnerable to contamination, the piped water supply is considered as the safest source of arsenic-free water. In the sampled village, during the survey period, purified-surface-water distributed through pipes was the only known source of arsenic-safe drinking water. The piped water project was implemented by the government during 2011-12. It was made accessible freely for public at certain locations of the village at specific times of a day. Therefore, the distance from a household's location to the piped-water source becomes an important factor in the adoption decision. The greater the distance, the adoption turns out to be more costly. The intermittent nature of the piped water supply increases the cost of collection and is also expected to matter in the adoption decision. First, there can be possible mismatch between a household's preferred time for collection of water and the fixed supply-time of piped water. Second, there can be time-consuming queue for collection of water. It is possible that the households with higher per capita income are in a better position to negotiate these problems by paying people for collection of water. If water is supplied free of cost, which was the case in the sampled village, one expects that the per capita income of the households would not affect the adoption decision. But the cost related to intermittent nature of the supply may make adoption easier for the higher per capita income households. Education increases awareness and the households with more literate persons are expected to adopt the piped water sources with higher probability. The percentage of female members in the households may increase adoption rate from two different aspects. First, the female members of the households are more concerned about the health and hygiene of the household. Second, if some of the female members are not gainfully employed, the presence of such members may alleviate the cost of collection for the households. The sampled village had presence of households belonging to Hindu and Muslim religions. They live clustered in segregated locations. The religion as such is not expected to affect the adoption decision. But, if the location of piped water source is nearer to a particular cluster, it may act as a disincentive for the households belonging to the other cluster[4].

Studies about issues related to adoption of arsenic-safe sources of water are scarce in the literature. On the one hand, there are studies like [2, 3, 1, 14, 18, 28] which analyse the technological aspects of adoption. They study the cost effectiveness of alternative feasible technologies. On the other hand, there are studies in economics which discuss adoption of safe-water sources and its benefits in the case of water-borne diseases like diarrhoea. While [15, 23] focus on health benefit of piped-water adoption in such cases, the papers like [29, 5] respectively show that the social network and religious segregation play an important role in piped water adoption in rural India. Although, in Morocco, Devoto et al. [12] shows that the ensuing health benefit is not the cause adoption of piped water, in Uganda Onjala et al. [13] i.e. [24] shows, the

2 Although household water treatment and safe storage is proved to be somewhat effective against microbial contamination, it is not very effective against arsenic contamination. See Amrose, Burt and Ray [15] for details.

3 People having poor nutrition were found to be affected more from arsenic toxicity than the people having an adequate nutrition rich food. Intake of nutritious diet especially with vitamins such as A, C and E is essential for arsenic mitigation [21, 25].

4 On practice of untouchability in Indian villages, see Dasgupta and Pal [21] i.e. [10].

risk perception of drinking unsafe water matters in adoption decision. Both these papers, however, agree on that the cost of adoption deters adoption. In case of Bhutan, Rahut et al. [16] i.e. [26] highlights the role of household income in adoption decision. According to their finding, the higher income households adopt more. In a closely related paper, Delaire et al. [17] analyses the household drinking water practices in two villages in arsenic-affected Murshidabad district of West Bengal, India in year 2014. The paper shows that despite low arsenic awareness, 52.9% of the households adopted safe water sources. They find the adoption decision was guided mainly by the fear of microbial contamination, smell and taste of the available water sources, and supported largely by purchase of safe water, produced by small scale firms, operating in the area. Therefore, adoption decision had a bias in favour of the higher per capita income households. However, the prevention of arsenicosis occurs as a co-benefit in Delaire et al. [17] and the supply of piped water plays a non-significant role. In contrast, this paper focuses exclusively on piped water adoption behaviour of households, who has suffered from arsenicosis.

In our study out of 707 sampled households although only 51% are arsenic affected, 62% adopted the piped water source. The paper shows that the arsenic affected households adopt the piped water source at 35% higher probability than the arsenic unaffected households. It also analyses the role played by the factors such as extensiveness of arsenicosis in a household (measured by percentage of family members arsenic affected), intensity of symptoms of arsenicosis in a household (measured by the percentage of certain arsenic related symptoms appeared in the household) and the years of experience about arsenicosis in a household, in the adoption decision. The paper finds that of the three factors mentioned above, the years of experience about arsenicosis matters the most in the adoption decision. Therefore, the risk perception of not using an arsenic-safe source is higher among the households that have long experience of suffering from the related ailments, the social and economic loss. The paper also finds that in the sampled village the Hindu households, who were in minority, adopted less because of distance of the piped water source from their locational cluster. As expected, the results show, the piped water being freely available, the per capita income of the households does not matter in the adoption decision; but the time cost is alleviated more by the higher per capita income households by showing higher probability of adoption.

The contribution of the paper in the literature is manifold. First, it shows that the arsenic affected households adopt the piped water source at higher probability than non-affected households. Second, the households with longer history of arsenic-related illness adopt more than the households showing more extensive or intensive spread of the symptoms among the household members. Third, location of the piped water sources in a clustered village matters in adoption decision. Fourth, the intermittent supply of piped-water may bias the adoption in favour of higher per capita income households, even if it is supplied free by the government. For policy-making, the results suggest that greater adoption of piped water sources in arsenic affected villages can be facilitated if the awareness is spread through the households, who suffered from arsenicosis for a long time. The piped water sources must be located more evenly in the clustered villages for greater adoption. A more continuous supply of piped water may remove the high-income bias from adoption of piped water in arsenic affected villages.

The paper is organized as follows. Section 2 describes the methodology, the data collection and the data respectively. Section 3 presents the results. Sections 4 and 5 discuss the policy implications and highlight the conclusions respectively.

2. Materials and Method

In an arsenic affected area, the households are expected to adopt an arsenic-safe source of drinking water. It is part of their mitigation strategy against arsenic related health and social hazards. However, the probability of adoption may differ between the households already suffering from arsenicosis and the unaffected households. It may also vary depending on the spread, intensity of arsenicosis in the household, the length of experience about such disease in the household, the costs of adoption of safe-water sources, the economic-demographic factors like religion, the household income and education, the percentage of female members at the household. The study controls for all the other factors to check the way the incidence of arsenic related health hazard affects a household's adoption decision of piped water source.

For our study we use a discrete-choice probit model where the binary dependent variable denoting the household's choice Y_i takes a value of 1 as the household chooses piped water source and a value of 0 as the household maintains status quo. The probit model is a statistical probability model with two categories in the dependent variable. Let X_i be the vector of regressors or the vector of the explanatory variables, which are assumed to influence the outcome Y_i. In the present study, we arrange the explanatory variables into three categories–a household's arsenic related health variables, cost of the adoption related variables and the variables related to demography of the households (later in Section 3 these independent variables are described in details). Specifically, we assume that the probit model takes the form

$$p_i = \Pr(Y_i = 1|X_i) = \Phi(X_i\beta) = \int_{-\infty}^{X_i\beta} \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-Z^2}{2}\right) dz$$

where, p_i denotes the probability of finding $Y_i = 1$ given X_i, and Φ is the Cumulative Distribution Function (CDF) of the standard normal distribution. The set of parameters β are typically estimated by maximum likelihood method. The CDF constrains the probability to lie between 0 and 1 (i.e. $0 < \Phi(z) < 1$, for all real numbers z), or $\lim_{z\to+\infty} \Phi(z) = 1$ and $\lim_{z\to-\infty} \Phi(z) = 0$. Since $\Phi(.)$ has the standard normal CDF, $\widehat{\beta}$ is the probit estimator and $\widehat{Y}_i = \Phi(X_i\widehat{\beta})$ is the fitted probability.

For interpreting the coefficients of the probit regression, the marginal effects are needed to be calculated. The marginal effects show the change in probability when the predictor or independent variable increases by one unit. For continuous variables this represents the instantaneous change given that the 'unit' may be very small. For binary variables, the change is from 0 to 1, so one 'unit', as it is usually thought. The relationship between a specific variable and the outcome of the probability is interpreted by means of the marginal effect, which accounts for the partial change in the probability. The marginal effect associated with continuous explanatory variables say, X_{iK} on the probability $\Pr(Y_i = 1|X_i)$, holding the other variables constant, can be derived as: $\frac{\partial p_i}{\partial x_{ik}} = \Phi'(X_i\beta)\beta_K$ where Φ' represents the probability density function of a standard normal variable. Discrete changes in the predicted probabilities constitute an alternative to the marginal effect when evaluating the influence of a dummy variable. Such an effect can be derived from the following:

$$\Delta = \Phi(\bar{X}\beta, d = 1) - \Phi(\bar{X}\beta, d = 0).$$

The marginal effects provide insights into how the explanatory variables shift the probability of frequency of arsenic-safe supply sources adoption. In this paper, the marginal effects are calculated for each variable while holding other variables constant at their sample mean values.

The empirical analysis in this study uses a primary database created by School of Environmental Studies, Jadavpur University (hereafter SOES, JU). It was collected during 2015-2016 from the village Kolsur of block Deganga in the district North 24-Parganas (West Bengal, India) which is known to be an arsenic affected area. The data set contains data both on arsenic affected households and arsenic unaffected households. The data was obtained by directly interviewing the households of the village. For this study, we surveyed 707 households selecting every alternative household living in the village. During the survey period, piped water was the only source of arsenic-safe drinking water in the village. The piped water project was implemented by the government during 2011-12. It was made accessible freely for public at certain locations of the village at specific times of a day. The sample of households includes both arsenic affected and arsenic unaffected households and the households that have adopted piped water and that have not done so. The survey prepared a detailed questionnaire and asked the households whether they have adopted piped water source or not; whether they have arsenicosis in the household and if so, it asked about the spread, the intensity and the time-duration of suffering from it. The survey also includes questions on cost of the adoption of arsenic safe water supply sources and demographic information of the household. The dependent variable of the regression analysis, the source dummy, is a binary variable that takes the value of 1 if the household adopts piped water source and the value of 0 otherwise. The independent variables are classified into three different groups: the arsenicosis related health variables, the adoption costs related variables and the demographic variables. Let us describe the components of each group of independent variables in details.

Arsenic related health variables: In this group we consider four different types of variables that may act as alternative indicators of arsenic related health hazard of a household. First, a dummy variable which takes the value of 1 if any member of the household has symptoms of arsenicosis and the value of 0 if no one is affected in the household. Second, a variable defined as SPREAD that measures the spread of arsenicosis at a household indicated by the percentage of household-members affected by arsenicosis. For example, if three members of a four member households show symptoms of arsenicosis, SPREAD of the household takes the value of 0.75. Third, a variable defined as INTENSITY that measures the intensity of arsenicosis at a household. For this, we consider six symptoms of arsenicosis *viz.* change in skin colour, white and black spots in skin, diffuse keratosis on palm/sole, spotted keratosis on palm/sole, non-healing ulcer on body, Bowens disease (suspected cancer) on body. If the members of a household show three of the six symptoms, INTENSITY of the household takes the value of 0.5. Fourth, a variable defined as YOI, that measures the average years of illness under arsenicosis at a household as indicator of experience about arsenic related health hazard. All these variables are expected to have positive coefficients in the regression.

Costs of adoption related variables: Since the piped water sources did not have any access fee in the sampled village, the costs of adoption of such sources were measured based on two different attributes. First, the distance to the piped water source in meters from the location of a household; the longer is the distance, the higher is the travel cost either in terms of physical exhaustion or in terms of transport. Second, the total time required for collecting the piped water in minutes that may include the time required for travel to the source and the time required for queuing at the source. Notice that since longer distance also means longer time of travel, the two measures of adoption costs can potentially be correlated with each other. However, we checked the correlation coefficient to be insignificant and include both as explanatory variables in the regression. Both the variables are expected to have negative coefficients in the regression.

Demographic variables: In this group we include four different variables which may influence a household's adoption decision. First, a dummy variable is introduced that captures the religion of a household. The religion may induce a behavioural variation in sourcing drinking water. In case of deep religious divide, which is widely reported in India[5], households from certain religious communities are not allowed to access certain sources of drinking water. Since the sample had households belonging only to two different religions, Hindu and Muslims, the religion dummy takes a value of 1 if the household is Hindu and the value of 0 if the household is Muslim. Second, since the presence of females in household is thought to bring in a change in the behaviour of a household in terms of health and hygiene[6], the percentage of female members in a household is taken as an

5 See Dasgupta and Pal [21].

6 See papers like [13] and [9].

explanatory variable. It is expected to have positive coefficient in the regression. Third, since education makes a household assess the risk of drinking from conventional sources in a better way, percentage of literate persons in a household is included as an explanatory variable. The percentage of literate persons in a household is calculated as number of its members of age 18 years or above having at least primary level of education. For example, if three members of a six member-household at their age 18 years or above have studied at least upto the primary level, the percentage of literate persons in the family is calculated as 50%. The percentage of literate persons in a household is expected to have a positive coefficient in the regression. Fourth, since the income strata of a household sometimes influences its behaviour along with affordability of the costs of adoption, the per capita monthly household income in INR has also been included as an explanatory variable. However, in our case since the piped water is freely provided to all the households, we do not expect it to significantly affect the adoption decision.

In the regression analysis we also include interaction of some of the explanatory variable described above. Since the time cost of collection can be alleviated by high per capita income households by employing people, we take interaction between time cost of collection and per capita income of the household. We expect the coefficient of it to be positive. We also interact the percentage of female members in a household both with distance to piped water source and collection-time, to check if the presence of higher percentage of female members in the household makes the cost barrier to adoption insignificant. We interact the religion dummy with the distance to piped water sources, to find whether location of the piped water source from clustered location of a particular community, which was the case in the sampled village, explains the adoption behaviour of the households belonging to the two different religious communities living in the village.

The descriptive statistics of the dependent and the main independent variables are presented in the Table 1 below.

Table 1. *Descriptive statistics.*

Variables		**Number of observations=707**		
		Mean	**Min**	**Max**
Dependent variable				
Source Dummy (adopted piped water supply=1, did not adopt piped water supply=0)		0.62 (0.49)	0	1
Independent variables				
Arsenic related health variables	Household Dummy (arsenic affected household=1, arsenic unaffected household=0)	0.51 (0.50)	0	1
	% of household members arsenic affected [SPREAD]	16.75 (20.11)	0	100
	% of arsenic affected symptoms (change in skin colour, white and black spots in skin, diffuse keratosis on palm/sole, spotted keratosis on palm/sole, non-healing ulcer on body, Bowens disease (suspected cancer on body) in households [INTENSITY]	13.98 (15.73)	0	66.67
	Average years of illness (years) [YOI]	9.60 (9.81)	0	25
Costs of the adoption related variables	Distance to the arsenic-safe drinking water source (Meters)	143.88 (147.41)	5	500
	Time required to collect drinking water (Minutes)	15.71 (7.67)	2	40
Demographic variables	Religion dummy (Hindu household=1, Muslim household=0)	0.41 (0.49)	0	1
	% of Females in the household	35.17 (11.90)	16.67	75
	% of Literate persons	63.86 (23.17)	0	100
	Per Capita Monthly household income (Rs.)	1821.06 (592.62)	500	5000

(Note: Standard deviations are in the parentheses).

Table 1 shows that out of 707 sampled households although only 51% are arsenic affected, 62% adopted piped water. There are households where all the members show symptoms of arsenicosis. On average 16.75% of the household members show some symptoms of arsenicosis. The variable INTENSITY has a mean of 13.98% in the sampled households. The average years of illness in arsenic related diseases across the households was 9.60 years. The average distance a household from an arsenic-safe piped water source was 143.88 meters and the total time required for collection on average was 15.71 minutes. 41% of the sampled households was Hindu in terms of religion. The average percentage of female members in a household was 35.17 and the percentage of literate persons in the household was 63.86. The average per capita monthly household income was 1821.06 in INR[7]. Therefore, the average per day per capita income of the households living in the village was less than US$1.

3. Results

We perform the probit regression using STATA. We run four different sets of the regressions in all of which the source dummy appears (piped water source adopted=1; 0 otherwise) as the dependent variable. They use the same set of controls, but differ from each other in their use of 'arsenic related health variables' as independent variable. We use arsenicosis dummy (if the household is arsenic affected=1, 0 otherwise), SPREAD, INTENSITY and YOI as alternative measures of 'arsenic related health variables' in the four different sets. For checking the effect of three different groups of independent variables mentioned above, in each set, we run two different specifications of the regression. The first specification considers only the 'arsenic related health variables' as regressor. The second one adds all three groups of independent variables and their interactions, as defined above, as control. Running the alternative specification helps

[7] 1 INR=0.015 US$ on 31.01.2016.

us to check robustness of the results. The results are described in Tables 2-4 below.

Table 2. *Adoption of piped water source: household arsenicosis effect.*

Independent variables	**(1)**	**(2)**
Household Dummy (i.e. arsenic affected household=1, arsenic unaffected household=0)	0.69**(0.10)	0.65***(0.10)
Distance to the arsenic-safe drinking water source (Meters)		-0.0007(0.0016)
Time required to collect drinking water (Minutes)		-0.01(0.04)
Religion dummy (Hindu household=1, Muslim household=0)		-0.76***(0.15)
% of Females in the household		0.0041(0.01)
% of Literate persons		0.0037(0.0028)
Per Capita Monthly household income(Rs.)		-0.0002(0.0002)
Religion dummy*Distance to the arsenic-safe drinking water source		0.0023***(0.0008)
% of Females in the household*Distance to the arsenic-safe drinking water source		-0.00001(0.00004)
% of Females in the household*Time required to collect drinking water		-0.0001(0.0008)
Time required to collect drinking water*Per capita Monthly household income		0.00002*(0.00001)
No. of observations	707	707
LRchi2	LRchi2(1)50.26	LRchi2(11)96.89
Prob>chi2	0.0000	0.0000
Pseudo R2	0.0535	0.1030

(Note: Standard errors are in the parentheses and ***, **, * respectively denotes 1%, 5% and 10% level of significance).

Table 2 reports the set of regressions with arsenicosis dummy as ‘arsenic related health variables’. In the first specifications run for this regression, the coefficient of the arsenicosis dummy turn out to be positive and significant at 5% level, implying higher rate of adoption of piped water among the households affected by arsenicosis. In the second specification, as the other controls are introduced, the value of the coefficient of the arsenicosis variable remains nearly unchanged with the level of significance going upto 1% level. The coefficients of most of the controls turn out to be insignificant, having their expected sign. The negative significant coefficient of the religion dummy (at 1% level of significance) implies that a Muslim household adopts the piped water with higher probability than a Hindu household. The result is strange because we cannot explain it by standard theory. Therefore, we investigate it further by studying the sign of the interaction term between distance to the piped water sources and the religion dummy, which turned out to be positive and significant at 1% level. The positivity of the interaction term implies that the Hindu households on average live away from the piped water source compared to the Muslim households. Recalling that the descriptive statistics in Table 1 shows that the village has Muslim majority, it seems, the piped water sources were provided closer to the location of Muslim households. The clustered location of the communities in the village explains the result. The result adds insight to findings of Balasubramaniam et al. [14] at district level Indian data that religious segregation affects the piped-water adoption decision. The other interesting result that we derive in the second specification is the sign of the interaction term between collection-time and per capita income of the households, which turns out to be positive at 10% level. Although per capita income of the households does not matter in adoption decision as the provision is free, there is weak evidence that the higher per capita income households alleviates the time cost of collection problem and adopts the piped water source in higher probability. The results also show that higher percentage of female members in a household does not significantly change the adoption behaviour. We also do not find evidence of higher adoption probability in households with higher percentage of literate members.

Similar to the case of set 1, we now describe the results of the regressions involving SPREAD (% of household members arsenic affected), INTENSITY (% of arsenic affected symptoms in households) and YOI [average years of illness (years)] as ‘arsenic health related variable’ separately in Tables 3 to 4 below.

Table 3. *Adoption of piped water source: effect of spread, intensity, YOI.*

Independent variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
SPREAD	0.01** (0.0026)	0.01*** (0.0027)				
INTENSITY			0.02** (0.0031)	0.02*** (0.0033)		
YOI					0.04** (0.0051)	0.04*** (0.0055)
Distance to the arsenic-safe drinking water source (Meters)		-0.0009 (0.0016)		-0.0010 (0.0016)		-0.0009 (0.0016)
Time required to collect drinking water (Minutes)		-0.01 (0.04)		-0.01 (0.04)		-0.02 (0.04)
Religion dummy (Hindu household=1, Muslim household=0)		-0.78*** (0.15)		-0.78*** (0.15)		-0.79*** (0.15)
% of Females in the household		0.0015		0.0045		0.0025

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
		(0.01)		(0.01)		(0.01)
% of Literate persons		0.0042 (0.0028)		0.0044 (0.0028)		0.0035 (0.0028)
Per Capita Monthly household income (Rs.)		-0.0002 (0.0002)		-0.0002 (0.0002)		-0.0002 (0.0002)
Religion dummy*Distance to the arsenic-safe drinking water source		0.0024*** (0.0007)		0.0025*** (0.0007)		0.0024*** (0.0008)
% of Females in the household*Distance to the arsenic-safe drinking water source		-0.00001 (0.00004)		-0.00001 (0.00004)		-0.000008 (0.00004)
% of Females in the household*Time required to collect drinking water		0.00009 (0.0008)		-0.00005 (0.0008)		-0.0001 (0.0008)
Time required to collect drinking water*Per Capita Monthly household income		0.00002* (0.000013)		0.00002* (0.00001)		0.00002* (0.00001)
No. of observations	707	707	707	707	707	707
LRchi2	LRchi2(1) 30.22	LRchi2(11) 79.33	LRchi2(1) 28.45	LRchi2(11) 78.82	LRchi2(1) 60.88	LRchi2(11) 108.15
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R2	0.0321	0.0844	0.0303	0.0838	0.0647	0.1150

(Note: Standard errors are in the parentheses and ***, **, * respectively denotes 1%, 5% and 10% level of significance).

In Table 3, in columns (1) and (2) for both the specifications the coefficient of SPREAD is positive and significant, the level of significance is going upto 1% level on introduction of controls, keeping the value of the coefficient unchanged. The coefficients of controls also show qualitatively similar result as in Table 2. As we repeat the regressions with INTENSITY and YOI as main explanatory variables, we find qualitatively similar results, as reported in columns (3)-(4) and (5)-(6) respectively. Therefore, the spread of arsenicosis among the household members, its intensity of occurrence among them and the history of arsenicosis in the household, all have positive significant effect on piped water adoption. But, the comparison of coefficients in Tables 3, clearly shows that YOI has the strongest impact on adoption, followed by INTENSITY and SPREAD.

Table 4 shows calculations of marginal effects (the predicted probabilities) of the 'arsenic health related variables' i.e. the arsenicosis dummy, SPREAD (% of household members arsenic affected), INTENSITY (% of arsenic affected symptoms in households) and YOI (average years of illness (years)) on adoption decision of the households. Since two different specifications have been run in each set of regressions, Table 4 reports the average marginal effect.

Table 4. *Average marginal effects.*

Households arsenic related health variables (Independent Variables) (no. of observations=707)	Average Marginal Effects	Standard Errors	z-statistic
Household Dummy (i.e. arsenic affected household=1) adopted arsenic safe piped water supply projects	0.74	0.02	32.38
Household Dummy (i.e. arsenic unaffected household=0) adopted arsenic safe piped water supply projects	0.49	0.03	18.15
SPREAD	0.0051	0.00090	5.66
INTENSITY	0.0061	0.0011	5.58
YOI	0.0139	0.0016	8.85

Notice from Table 4, the probability that an arsenic affected household adopts arsenic safe water sources is 35% higher than the probability that an arsenic unaffected household does so. However, the rise in probability of adoption due to higher spread of arsenicosis in a household or due to higher intensity of such illness in a household is very low calculated at 0.0051 and 0.0061 respectively. In contrast, the rise in average year of illness by 1 year, raises the probability of adoption by 0.01%. Therefore, we conclude that the risk perception of not using arsenic-free piped water source is higher among the households that have long experience of suffering from the related ailments, the social and economic loss.

4. Discussion

The paper studies the mitigation behaviour of the households in the arsenic affected regions by adoption of piped water sources. It uses primary survey data collected from the arsenic affected and unaffected households of Kolsur village in North 24 Parganas District of the State of West Bengal in India during 2015-16. It runs probit regressions that control for co-variates like adoption costs and demographic variables like religion, literacy, percentage of female at the household and per capita monthly household income, to find that the probability of adoption is higher among the arsenic affected households vis-à-vis the unaffected households. The paper also checks whether the spread, the intensity and the experience of such health hazards at the households also matter in the adoption decision and finds that their marginal impact on adoption decision is small. Among the three factors mentioned above, the paper finds, the years of experience matters the most in the adoption decision. Therefore, the risk perception of not using arsenic-safe piped water source is higher among the households that have long experience of suffering from the related ailments, the social and economic loss. While the factors like affordability (per capita monthly household income), awareness (the literacy) and the percentage of female members in the households play little role in adoption decision. Interestingly, the Muslim households in the sample were found to adopt more compared to the Hindu households. The paper explored the reason behind such a result. It turned out that the village had majority of the Muslim households. As the religious communities lived in locational cluster in the sampled village, location of the piped water source nearer to the Muslim cluster deterred the Hindu households from its adoption. The results also show, even if the piped water was provided free of cost, the time cost associated with intermittent supply of water created a bias in adoption in favour of the high per capita income households, as these households could possibly employ someone to negotiate the cost.

The paper contributes to the literature being one of its kind on the voluntary adoption of arsenic-safe piped water source in an arsenic affected area. The earlier adoption studies such as Delaire et al. [17] i.e. [11] could not distinguish between adoption against microbial contamination and adoption against arsenic contamination. It was specially so because while the microbial symptoms get remedied in short duration, the manifestation and remedial of arsenic related symptoms take longer time. This paper contributes by studying the piped water adoption behaviour of the arsenic affected households via-vis arsenic unaffected households. It also studies the effect of spread, intensity and experience of arsenic related symptoms on piped water adoption decision. The results derived in the paper have important policy implications. For policy-making, the results suggest that greater adoption of piped water sources in arsenic affected villages can be facilitated if the awareness is spread through the households, who suffered from arsenicosis for a long time. The piped water sources must be located more evenly in the clustered villages for greater adoption. A more continuous supply of piped water may remove the high-income bias from adoption of piped water in arsenic affected villages, where it is provided free of cost.

5. Conclusions

The paper studies the adoption of arsenic-safe piped water source both by the arsenic-affected and unaffected households. The data is collected from Kolsur village in West Bengal, India. Controlling for the other factors, it is found that the households affected by arsenicosis are more likely to adopt piped water source as mitigation strategy compared to the unaffected households. The paper analyses separately the role of the spread of arsenicosis and the intensity of its symptoms among the household members in adoption piped water source. The effect of the years of experience about the health and social hazards associated with arsenicosis is also checked. The paper finds that although the marginal impact of all these factors on the adoption decision is small, the effect of years of experience is stronger than the other two factors. Among other factors, it seems that the uneven allocation of publicly-provided free piped-water sources and its intermittent supply discourages its adoption by raising the cost of adoption. Therefore, the households either located near the source, or having higher per capita income adopt it more easily than the households located further away from the source and the poor.

The results derived in the paper have important policy implications. The results suggest that greater adoption of piped water source in arsenic affected villages can be facilitated if the awareness is spread through the households, who suffered from arsenicosis for a long time. The piped water sources must be located more evenly in the villages, where population lives in spatial clusters, for greater adoption. A more continuous supply of piped water may remove the observed high-income bias from adoption of piped water in arsenic affected villages, where it is freely provided.

There are some limitations of the study undertaken in the paper. The most important of them is its small sample size. A more extensive study may externally validate the results of the paper, which remains our future research agenda.

Conflicts of Interest

All the authors do not have any possible conflicts of Interest.

Availability of Data and Material

Would be made available on request.

Code Availability

Would be made available on request.

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