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Determinants of household's piped water connection in arsenic contaminated areas of the Red River Delta, Vietnam

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A B S T R A C T

Arsenic in drinking water is a severe public health risk in Vietnam especially in the Red River Delta (RRD), northern Vietnam. Located in the RRD, Hanam is the most affected province by arsenic contamination of groundwater. Several programs have been initiated and implemented in Vietnam especially in the rural areas to address the problems of arsenic in drinking water, among those piped water from centralized water plants. However, it is the fact that like many developing countries, in Vietnam efforts have been focused mainly on engineering aspect of technologies, while the nature of water users' needs is neglected. This study assessed the determinants of piped water connection in arsenic contaminated areas of the RRD based on a field survey of 443 households in Hanam province. We found that, most of the respondents in RRD were aware of arsenic contaminated water but did not have deep knowledge on the issue and long-term health effect of consuming arsenic contaminated water. Connection fee, arsenic awareness index and household expenditure presented the most influential factors affecting the decision of getting connected. We discussed the implication of connection subsidies, awareness raising and collective action policy for providing safe water for the welfare of all society.

1. Introduction

Arsenic in drinking water is a problem that came to prominence in Vietnam in the mid-1990s. At the same time, the rural population began to change the source of their drinking water from surface water, which was often contaminated by pathogenic bacteria, to pathogen-free groundwater (Berg et al., 2001). The construction of tubewells in Vietnam commenced in the 1990s. The United Nations Children's Fund (UNICEF) in Vietnam has so far supported the implementation of over 150,000 tubewells while local communities and individuals have constructed an even greater number. It is estimated that around 20% of Vietnam's population consumes water from tubewells in the Red River Delta (RRD) and Mekong River Delta (MRD) of the country (MoNRE, 2009; Murcott, 2012). Unfortunately, groundwater in Vietnam has been found to be contaminated by naturally occurring arsenic (As) (Dang, 1992; Berg et al., 2001; Jessen, 2009). RRD in northern Vietnam is the region of the country that is most badly affected by arsenic contamination. The provinces in the delta that have the worst arsenic pollution are Hanam,

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Namdinh, and Hanoi, which are all situated along the Red river (UNICEF, 2001; NIOEH, 2003; Le et al., 2007; MoNRE, 2009; Jessen, 2009; Murcott, 2012). According to recent surveys (MoNRE, 2009), the arsenic concentration of around half of the tubewells in Hanam province is above 50µg/l. This is significantly above safe level of 10µg/l prescribed by the World Health Organization (WHO). In many of the surveyed locations in Hanam province, the levels of arsenic contamination were found to be as high as in Bangladesh[1].

The toxic properties of arsenic have been known for centuries. The presence of arsenic in drinking water is considered to be one of the most significant environmental causes of cancer in the world (Smith et al., 2000). Long-term exposure to high levels of arsenic leads to a wide range of other health problems that include arsenic poisoning, cardiovascular disease, neuropathy, and gangrene (UN 2001; Kapaj et al., 2006; Hopenhayn, 2006; Yuan et al., 2007). As a result of contaminated water supplies, Vietnam is currently facing long-term epidemic diseases related to arsenic exposure. Between 0.5 and 1.0 million Vietnamese people are expected to be at chronic risk from arsenic exposure (Berg et al., 2007). In 2003, Vietnam reported first cases of arsenicosis (NIOEH, 2003). Separately, Agusa et al. (2005), Dang et al. (2006), and MoST (2015) conducted studies on the health impacts of arsenic exposure in the RRD and observed significant positive correlation between arsenic concentrations in groundwater and in urine and hair of local residents. To date, approximately 30 cases of arsenicosis have been identified in Vietnam, with majority occurring in RRD. This is a relatively low number of cases in comparison with other countries that are affected by arsenic contamination in South and East Asia like China, Bangladesh, and West Bengal. However, this situation may be because tubewells have only recently been introduced in Vietnam. As a silent killer, the symptoms of arsenic toxicity may take several years to develop (WHO 2001). Hence, current arsenic-linked health problems in Vietnam are most likely to only be the tip of the iceberg.

In rural areas, especially in highly arsenic-contaminated areas in RRD, a variety of household-based interventions i.e. rain water, surface water, sand water filter, household commercial water filters have been used to decrease the level of arsenic in water with various levels of success. Despite more than a decade of intensive research aiming at mitigation of the arsenic problem, the people in the RRD are still consuming arsenic-contaminated drinking water (Berg et al., 2001; Nguyen et al., 2009). The Government of Vietnam recognizes that arsenic contamination of groundwater causes serious environmental problems and that it has serious negative health effects. In recent years, several programs and initiatives have been initiated by government to address the problem of arsenic in drinking water. The government's favored solution is to provide households with safe piped water from centralized water plants. This is thought to be the best and most sustainable solution, especially in the rural areas. However, as is the case in many developing countries, the plans have, so far, mainly focused on solving engineering challenges and have neglected the needs of end users (Nam & Son 2010). Criticisms of this approach focus on the failure of such programs to take account of demographic and financial realities (Whittington et al., 1993). Since the mid 1980's, a new vision based on a demand-oriented approach has emerged. This approach asserts that regulators and water providers need to understand household water use behavior, acceptance/ability and the settings against which they operate in response to the new programs. Household's choice of water source and water connection was first acknowledged by Whittington et al. (1987) and developed by several authors among others Basani et al. (2004), Larson et al. (2006), Nauges and van den Berg (2006), Nauges and Strand (2007), Basani et al. (2008) and Dagnew (2012). Authors generally agree that two groups of independent variables, one relating to household characteristics (income, education, size and composition etc.) and another relating water source attributes (i.e., connection fee, price, distance to the source, quality, reliability) should enter the choice model. Source attributes account

[1]Bangladesh is reported to be the biggest arsenic calamity in the world in terms of affected population. The concentration of arsenic in groundwater in some places of Bangladesh has been found to be as high as 2,300µg/l.

for heterogeneity in water from different sources while household characteristics account for difference in tastes, opportunity cost of time, and perception of health benefits from improved water (Whittington & Nauges , 2010). Regarding the people's perception and preference for improved water quality in arsenic-affected developing countries, the study of World Bank (2003), Ahmad et al. (2006) analyzed rural people's preferences for arsenic-free drinking water options in Bangladesh. A particular focus was on rural households' demand for piped water supply compared with that for other household/community-based arsenic mitigation technologies. The analysis revealed a strong demand for piped water and scope of adequate cost recovery. Between piped water and other arsenic mitigation technologies, the preference of rural people was found to be predominantly in favor of the former. The similar result was observed in the study of Abhijit (2011) on economic analysis of arsenic in water in West Bengal. 100% respondents had positive response for getting arsenic-safe drinking for their family.

There are some works accomplished on arsenic awareness of residents in Vietnam. The study of Tran and Ross (2009) focused on groundwater dependent residents in Hanoi and concluded that household awareness of arsenic was low. Factors such as location, gender, occupation, income and level of education significantly influenced a respondent's knowledge of arsenic contamination. The research of Vo et al. (2017) on drinking water in the context of arsenic contamination options in the MRD found that unsafe groundwater is still being used for drinking in the southern Vietnam, and that household knowledge about arsenic contamination is generally poor. The study showed that, sand filter and safe water treatment equipment are cost-effective solutions that should be promoted. The review of a limited number of recent papers on economic aspect of arsenic in water in developing economies reveals a discrete and incomplete picture of the issue. Little effort has been made to understand people preference for arsenic-free water and whether they are willing to get connected to the rural piped water supply. The lack of such kind of information is particularly noticeable in Vietnam, where no empirical study has been done so far. The present paper contributes to the still short literature on determinants of water connection in developing countries with Vietnam as a case study. In this article we estimate the factors affecting piped water connection in arsenic-contaminated areas of the RRD of Vietnam using data from a survey of 443 households conducted in 2015.

2. Research Methodology

2.1. Study Sites

The research targeted two rural districts of RRD province of Hanam namely Duy Tien and Binh Luc. As of 2013, Binh Luc has a population of 133,180 and covers an area of 144 km^2, while Duy Tien has a total area of 121km^2 with a population of 116,088 persons. Both districts have been identified as arsenic hotspots in Hanam province. According to MoNRE survey, the concentration of arsenic in drinking water in Binh Luc and Duy Tien is 30-40 times higher than National technical regulation on drinking water quality. In both districts there are different sources of water including piped water, tubewell, and rain water.

2.2. Data Collection

Data were collected through households field survey and face-to-face in-depth interviews with relevant actors and stakeholders in August and September 2015 in RRD province of Hanam. The survey development process involved both focus group discussions (FGDs) and pre-testing of a draft of the questionnaire.

2.2.1 Sample Size and Sampling Strategy

In this study, we used 'households' variable to estimate the number of surveys to conduct. With the desired degree of statistical confidence of 95%, then the sample size would need to be approximately 400 households. The number of households surveyed was proportionately allocated in each district, using the total number of households per district as the basis of allocation. For each district, the sampling units were chosen through a two-stage sampling strategy. The first stage was to divide the households in each district into two groups namely (i) connected and (ii) not connected householders. The second stage involved simple random selection of householders from each group. The list of the surveyed households was done by the researchers. The number of householders surveyed per district was shown in Table 2.

2.2.2. Focus Group Discussions

FGDs were conducted before the survey took place with representative of Center for preventive medicine, local communities, and research institutes. These meetings aimed to collect information to design and finalize the questionnaire format.

2.2.3. Key Characteristics of the Survey Instrument

The final questionnaire comprised four main parts. The first part of the questionnaire sought qualitative information on people's perception and attitudes on arsenic contamination. The second part aimed at collecting information about the households' water use practices and the factors affecting households' decisions about whether or not to connect to the piped water systems. The third part of the questionnaire consisted of questions about the socio-economic characteristics of the respondents. These included age, gender, education, household size, income, expenditure, assets, etc. These characteristics were used to identify those which may have most impacts on the water use practices and household water choice decision. The last part of the questionnaire was on debriefing questions for enumerators to complete.

2.2. Model Specification

To determine the factors affecting the household's connection to piped water in arsenic contaminated areas of the RRD, logistic regression model was applied. The model is similar in nature to the one developed by Basani et al. (2004, 2008), Nauges and Strand (2007) and Dagnew (2012). The purpose of logistic procedure is to model the dependence of a nominal categorical response on a set of discrete and/or continuous predictor variables. The econometrics analysis allowed us to estimate connect-to-piped water probability. This model also allowed us to identify the main barriers and potential constraints to connection. More formally, let $\boldsymbol{y}$ be the binary outcome variable indicating failure/success with 0/1 and p be the probability of y to be 1, p = prob(y=1). Let $x_1, \dots, x_k$ be a set of predictor variables, then the logistic regression of y on $x_1, \dots, x_k$ estimates parameter values for $\beta_0, \beta_1, \dots, \beta_k$ via maximum likelihood method of the following equation.

$$\text{logit}(p) = \log(p/(1-p)) = \beta_0 + \beta_1 \times x_1 + \dots + \beta_k \times x_k$$

In terms of probabilities, the equation above is translated into

$$p = \exp(\beta_0 + \beta_1 \times x_1 + \dots + \beta_k \times x_k)/(1+\exp(\beta_0 + \beta_1 \times x_1 + \dots + \beta_k \times x_k)).$$

In this exercise, the dependent variable is the household's choice to get or not to get a piped connection. The independent (exogenous) variables in the function are connection fee, arsenic knowledge, and households' socio-demographic factors. The basic system of equation of interest in this study can be written in a general functional form as follows:

Probability of piped water connection = f(connection fee, arsenic knowledge, location, households' socio-demographic factors, etc.)

Table 1
Description of variables in the model

Variable	Description	Type	Source of information	Reference
Fee	Connection fee	Continuous variable, logarithmic form	Household survey and cross check with local information	Basani et al.(2008), Dagnew (2012)
Aware Index	Arsenic awareness of respondent	Variable using point system	Household survey and scoring system	ICEM (2011)
Location	Location of respondent	Duy Tien = 1; Binh Luc = 0	Household survey	Basani et al.(2008)
Expend	Average household expenditure	Continuous variable, logarithmic form	Household survey and cross check with local information	Basani et al.(2008)
Income	Level of household income	Continuous variable, logarithmic form	Household survey and cross check with local information	Nauges and van den Berg (2006), Nauges and Strand (2007), Larson et al. (2006)
Working _person	Number of people in working age	Continuous variable	Household survey	
Edu	Education level of respondent	Variable using point system from 1 to 5. The person with no education will get 1 point, while college graduated person will get 5 points	Household survey	Nauges and van den Berg (2007,2008), Larson et al. (2006), Dagnew (2012)
Age	Age of respondent	Continuous variable	Household survey	

3. Result and Discussion

3.1. Socio-economic Characteristics of Respondents

The survey in Duy Tien and Binh Luc included 443 households. Respondents were randomly selected from these two areas – an area affected by large scale arsenic contamination. Table 2 lists the districts surveyed and the number of respondents interviewed in each area.

Table 2
Distribution of respondents

	Number of household	%
Duy Tien district	209	47.2
Binh Luc district	234	52.8
Total	**443**	**100**
Connected household	323	72.9
Not-connected household	120	27.1
Total	**443**	**100**

The average age of the respondents was 52 and is relatively similar across the two districts. Men accounted for 41% of the respondents and 94.6% of the respondents were married. In the surveyed areas, most of the respondents are relatively well educated with more than 80% respondents having at least the secondary school education level. Only 5.4% of the respondents were illiterate and a small percentage (13.7%) had only passed primary education. 7.5% of the respondents have finished college. Those who finished high school account for 19.3% of total respondents. Approximately 62.2% of the respondents reported a level of monthly income ranging between VND 1 to 5 million; 20.8% of respondents reported a level monthly income below VND 1 million; 13.4% of respondents reported a level of income between VND 5 and 10 millions, and 3.6% above VND 10 million. Average household income was estimated to be approximately VND 6.89 million per month. The data on income is similar to the information provided by Hanam DSO. With respect to the ownership of assets, 80% of the households have indicated owning a motorbike; 93.2 have a TV set, and 89% use mobile phones. The proportion of household having air conditioner and washing machine in the sample is 21% and 30% respectively; 18% have a personal computer at home and 16% have an internet connection. 3% of the respondents owned an automobile.

3.2. Household Awareness of the Arsenic Problems

3.2.1. Awareness of Arsenic Problem

The survey results revealed that 23.5% of respondents had heard about arsenic contamination of their district in the past 12 months on mass media many times and 33% confirmed to hear of such issue a few times. 25.5% mentioned they had never heard of arsenic in water in media

In order to assess the household perception of the health impact of consumed arsenic contaminated water, respondents were asked whether or not they know the symptoms of arsenicosis. Six symptoms of arsenicosis including (i) Black, white or red spot over the body; (ii) Hand and feet become rough to touch; (iii) Legs swells up; (iv) Losing the feelings of hands and legs; (v) Sore over hand and leg and (vi) Cancer were shown to the respondents. Despite the fact that living in arsenic contaminated area, only 41.5% of respondents reported that they know some of the symptoms. Even those who have some knowledge about them could not clearly describe the symptoms. During the course of survey, the respondents were also asked whether or not they knew anyone who was affected by arsenicosis in their commune. Only a few respondents (10%) had heard of cases of arsenicosis in their commune. The number of reported case was only two. Further questions of arsenic knowledge were developed and asked. Approximately 50% of respondents reported that it may take some years for arsenic poisoning to manifest itself and that the prolonged use of arsenic contaminated water could lead to gangrene, cancer or even death. The capacity of household to afford the cost of treatment if a family member is affected by arsenicosis is an important issue that could strongly impact household decision of getting connected to piped water. Only 16% respondents felt that they could afford the cost of treatment, while around 71 % said it would be difficult or cannot meet the cost of treatment. Given the seriousness of arsenic contaminated water, as much as 46% of respondents recognized arsenic as a threat to the family's health and felt that to ensure safe water in the commune was extremely important. The survey results showed that 38.5% respondents had checked their drinking water during the last 12 months and took measures to protect themselves from arsenic contamination. However only 10% believed those intervention are effective to mitigate the arsenic in water. The lack of understanding and trust about water quality and reliability of arsenic mitigation options is clearly a significant obstacle for dealing with arsenic issue in Vietnam. Information provision and building the trust are important areas that need more effort and actions.

3.2.2. Public Awareness Index

In order to assess public awareness of arsenic issue, an arsenic awareness index was constructed using a point scoring system based on the work of ICEM (2011). A household receiving 0 points would be qualified as absolutely not arsenic aware while a household receiving 10 points would be qualified as very arsenic aware. Table 3 shows the awareness index in the studied areas. Public awareness about arsenic issue is relatively low. In the sample, none of the respondent achieved the highest possible mark for arsenic awareness of 10 points. Only 0.2% of the respondents gained the almost highest mark for arsenic awareness (9) and 11.4% had the high mark from 6 to 8. 15.3% of the respondents had average level of awareness (mark 5) while the awareness of approximately 73% of the respondents is low (mark 0 to 4). The connected households had the higher arsenic awareness than those who had not connected to the system.

Table 3
Arsenic awareness index

		1	2	3	4	5	6	7	8	9	10	Total
Not connected household		14	25	32	35	11	2	0	1	0	0	120
	%	11.7	20.8	26.7	29.2	9.2	1.7	0	0.8	0	0	100%
Connected household		0	56	84	78	57	35	10	2	1	0	323
	%	0	17.3	26.0	24.1	17.6	10.8	3.1	0.6	0.3	0	100%
Total sample		14	81	116	113	68	37	10	3	1	0	443
	%	3.2	18.3	26.2	25.5	15.3	8.4	2.3	0.7	0.2	0	100%

3.3. Analysis of Water Connection Decision

To run the model, the data was cleaned for missing information. The sample size was reduced to 338 usable observations. Correlations coefficients between the possible pairs of variables are shown in the Table 4.

Table 4
Correlation matrix of possible independent variables

	log_fee	Aware Index	Location	Age	Edu	Working_person	log_ expend	log_ income
log_fee	1.00	-0.11	0.11	-0.19	-0.04	-0.00	0.14	0.15
Aware Index	-0.11	1.00	-0.36	0.12	0.05	0.08	0.18	0.08
Location	0.11	-0.36	1.00	0.03	0.13	0.04	-0.16	0.06
Age	-0.19	0.12	0.03	1.00	-0.21	-0.14	-0.34	-0.28
Edu	-0.04	0.05	0.13	-0.21	1.00	0.12	0.23	0.34
Working_ person	-0.00	0.08	0.04	-0.14	0.12	1.00	0.38	0.15
log_expend	0.14	0.18	-0.16	-0.34	0.23	0.38	1.00	0.49
log_income	0.15	0.08	0.06	-0.28	0.34	0.15	0.49	1.00

It appears that location is correlated with awareness level of respondent. Age, edu and working_person are likely correlated with income and expenditure of the households. Expenditure and income are strongly correlated. Four variables were chosen and included in the logistic regression model namely log_fee, Awareness Index, log_expend and Edu. From among the variables included in the analysis, three independent variables (connection fee, arsenic awareness index and household monthly expenditure) were found to have a statistically significant impact on the likelihood of a household having a private piped connection (Table 5). Based on the results presented in Table 5 and odds ratio, the estimated coefficient *log_fee* was well determined and suggests that a 5.3% decrease in the odds of getting connected on average for a 1% increase in *log_fee* since exp(-5.417×1%) = 0.947172. The estimated coefficient for *log-expenditure* is meaningful and implies that a 0.7% decrease in the odds of getting connected on average for a 1% increase in *log_expenditure* since exp(0.720×1%) = 1.007226. This is probably due to the fact that households with larger expenditures are households with better livelihoods and these householders are able to pay the advance connection payments required by the water supply utility.

Arsenic awareness index has an odds ratio of 1.927069 (exp(0.656) = 1.927069), implying that a 92% increase in the odds of getting connected on average for a one-unit increase in arsenic awareness index, controlling for all other factors in the model. The higher the people awareness on arsenic contaminated water, the higher the probability of connection to piped water. Given this, the encouraging conclusion is that local people have generally responded positively to the water contaminated issue. However, attention should be paid to the cost of connection that could negatively impact the decision of local people. Other independent variable *Edu* is not statistically significant and cannot be considered as having an effect on the likelihood of household to have private piped water connection.

Table 5
Households water connection model (Logit model)

	Dependent variable			
	(1)	(2)	(3)	(4)
log_fee	-5.724*** (0.659)	-5.356*** (0.656)	-5.501*** (0.687)	-5.417*** (0.690)
Aware Index		0.554*** (0.210)	0.579*** (0.214)	0.656*** (0.229)
log_expend			0.629*** (0.335)	0.720** (0.348)
Edu				-0.345 (0.262)
Constant	3.978*** (0.499)	-2.440*** (0.698)	1.986*** (0.719)	2.781*** (0.959)
Observation	338	338	338	338
R^2	0.735	0.756	0.766	0.770
chi^2	204.731***	212.766***	214.788***	216.553***
Note:				*p<0.1;* p<0.05; p<0.01

A closer look to the marginal effects of connection model (Table 6) gives almost the same picture. All the estimated coefficients are plausible except for the *Edu* estimate. This model provides us with some degree of confidence about the factors that influence connection. It was found that connection fee represented one of the most influential factors affecting the connection decision of households.

Table 6
Marginal effects of connection model

Variable	Dependent variable			
	dF/dx	Std. Err.	z	P>[z]
log_fee	-0.107	0.04274	-2.505	0.01225
Aware Index	0.01297	0.00684	1.896	0.0579
log_expend	0.01424	0.00854	1.667	0.09554
Edu	-0.00682	0.0059	-1.156	0.2476
Observation	338			

This result rate appears to be similar with those of Basani et al. (2004). In the study of *Water demand and welfare effects of connection: Empirical evidence from Cambodia*, apart from ethnic factor, connection fee and expenditure were found to have strong impacts on connection decision of local people.

4. Conclusion and Policy Implication

Arsenic in drinking water is a severe public health risk in Vietnam. The RRD in northern Vietnam is among the region most suffered from arsenic contamination. From the early 2000s, the development of centralized water treatment plants/piped water system, have been and will continue to be initiated in major provinces of Vietnam especially in RRD, where the water is heavily contaminated by arsenic. Such investment projects will contribute to quality improvement of clean water, provided that they are effectively operated and that a large percentage of water users (such as households) connect to the system. Most of the respondents in RRD were aware of environmental issue in general and arsenic contaminated water in particular in their communes. This is reflected in the relatively high percentage of respondents which has some knowledge on arsenic symptoms. Nearly half of the respondents recognized arsenic as a threat to the family's health and felt that to ensure safe water in the commune was extremely important. However most of the respondents did not have deep knowledge on the issue and long-term health effect of consuming arsenic contaminated water. Connection fee, arsenic awareness index and household expenditure were found to be the most influential factors affecting the decision of getting connected. The results indicated that the higher arsenic awareness household seemed to have higher probability of getting connected than those with lower awareness level. Households with larger expenditures were more likely to get connected than those with smaller expenditures. The higher connection fee, the higher the probability of not getting connection to piped water. In order to promote household connection to the piped water in arsenic contaminated area of RRD, the number of actions should be taken:

Raising public awareness on arsenic contaminated issue. The lack of awareness of serious health effects of consuming arsenic contaminated water leads to the current unsafe water use in the study site. Clearly, this issue is an important area that needs more effort and actions. Raising public awareness is said to be high efficient as it is simple and cost saving and leading to change in attitude and behaviors of the residents. Thus awareness raising should be the starting point for any approach to deal with the arsenic problem and special attention should be paid to information and communication program.

Connection subsidies. Basani et al. (2004), Dagnew (2012) documented the negative impact of connection fee on probability of getting connected. The result of this study also supported this inference. High connection fee is one main obstacle for non-connected households. Poor and less-poor households will need financial support especially in the case where connections are made compulsory. This suggests a clear policy option – a connection subsidy scheme. This may represent an important step in process of providing safe water to all household. Financial mechanism should be established to facilitate this process.

Multi-stakeholder approach. This approach aims to bring together all major stakeholders in a new form of communication, consultation and decision-making on a particular issue based on the recognition of the importance of equity and accountability among stakeholders. In the case of safe water provision in Vietnam, the key stakeholders would likely consist of government, public and private sector, international donors, mass media, local people and societal networks. Joint initiatives with governmental and international organizations and donors to introduce new technologies, regulations, and quality standards; facilitate information exchange; provide financial assistance and develop collective actions are recommended. Moreover, the entry of private sector should also be welcomed in order to expand services and introduce fair competition in providing safe water for the welfare of all society.

References

Abhijit, D. (2011). *The economic analysis of arsenic in water: a case study of West Bengal.* PhD thesis submitted to the Jadavpur university. Kolkata, India

Ahmad, J., Goldar, B., & Misra, S. (2006). Rural communities' preferences for arsenic mitigation options in Bangladesh. *Journal of water and health*, *4*(4), 463-477.

Agusa, T., Inoue, S., Kunito, T., Kubota, R., Minh, T. B., Trang, P. T. K., ... & Tanabe, S. (2005). Widely-distributed arsenic pollution in groundwater in the Red River Delta, Vietnam. *Biomedical Research on Trace Elements*, *16*(4), 296-298.

Basani, M., Reilly, B., & Isham, J. (2004). *Water demand and the welfare effects of connection: empirical evidence from Cambodia* (No. 0429). Middlebury College, Department of Economics.

Basani, M., Isham, J., & Reilly, B. (2008). The determinants of water connection and water consumption: Empirical evidence from a Cambodian household survey. *World Development*, *36*(5), 953-968.

Berg, M., Tran, H. C., Nguyen, T. C., Pham, H. V., Schertenleib, R., & Giger, W. (2001). Arsenic contamination of groundwater and drinking water in Vietnam: a human health threat. *Environmental science & technology*, *35*(13), 2621-2626.

Berg, M., Stengel, C., Trang, P. T. K., Viet, P. H., Sampson, M. L., Leng, M., ... & Fredericks, D. (2007). Magnitude of arsenic pollution in the Mekong and Red River Deltas—Cambodia and Vietnam. *Science of the Total Environment*, *372*(2-3), 413-425.

Berg, M., Trang, P. T. K., Stengel, C., Buschmann, J., Viet, P. H., Van Dan, N., ... & Stüben, D. (2008). Hydrological and sedimentary controls leading to arsenic contamination of groundwater in the Hanoi area, Vietnam: the impact of iron-arsenic ratios, peat, river bank deposits, and excessive groundwater abstraction. *Chemical geology*, *249*(1-2), 91-112.

Dagnew, D.C. (2012). *Factors determining residential water demand in north western Ethiopia.* A project paper of Master of Professional Studies. Cornell University. USA.

Dang, M.N., Nguyen, K.H., Ha, C.K., Chander, B., & Nguyen, Q.H. (2006). Health impact of arsenic contamination in groundwater. Proceedings of National Workshop on Arsenic Contamination in Groundwater in the Red River Plain. 23 November 2006, Hanoi. National University. Hanoi. Vietnam.

Dang, V.C. (1992). Arsenic in geological formations in the Ma River upstream region (Son La Province) and its effect on the environment. *Proceedings of the Regional Conference on Environmental Geology. 1992, Hanoi. Vietnam. Department of Geology. Hanoi. Vietnam*.

Jessen, S. (2009). Groundwater arsenic in the Red River delta, Vietnam: Regional distribution, release, mobility and mitigation options. PhD Thesis. Technical University of Denmark. Lyngby. Denmark

Hopenhayn, C. (2006). Arsenic in drinking water: impact on human health. *Elements*, *2*(2), 103-107.

ICEM [International Centre for Environmental Management]. (2011). *The study on the revolving fund for household sewerage connection in Binh Duong and Vinh Phuc provinces*. ICEM. Hanoi. Vietnam.

Kapaj, S., Peterson, H., Liber, K., & Bhattacharya, P. (2006). Human health effects from chronic arsenic poisoning–a review. *Journal of Environmental Science and Health, Part A*, *41*(10), 2399-2428.

Larson, B., Minten, B., & Razafindralambo, R. (2006). Unravelling the linkage between the millennium development roles for poverty, education, access to water and householder water use in developing countries: Evidence from Madagascar. *Journal of Development Studies, 42*(1), 22-40.

Le, T.H., Tran, Q.T., Nguyen, K.H., Bui, V.T., & David, R. (2007). *Extended field trials of household iron removal plants to remove arsenic from groundwater.* Proceedings of the 2nd International Forum on Water Environmental Governance in Asia. Beppu, Japan. 03–04 December 2007, Beppu. Water Environment Partnership in Asia (WEPA) and Ministry of the Environment Japan. Tokyo. Japan.

MoNRE [Ministry of Natural Resources and Environment]. (2009). *Report on arsenic test results in Vietnam*. MoNRE. Hanoi. Vietnam.

MoST [Ministry of Science and Technology]. (2015). *Report of national project on assessing the changes of genes of infants exposed to arsenic*. MoST. Hanoi. Vietnam.

Mu, X., Whittington, D., & Briscoe, J. (1990). Modeling village water demand behavior: a discrete choice approach. *Water Resources Research*, *26*(4), 521-529.

Murcott, S. (2012). *Arsenic Contamination in the world - An international sourcebook*. IWA Publishing. London. UK.

Nam, P.K., & T.V.H. Son. (2010). *Household demand for improved water services in Ho Chi Minh City*. EEPSEA Research Report. Economy and Environment Program for Southeast Asia, Singapore.

NIOEH [National Institute of Occupational and Environmental Health]. (2003). *Case identification of arsenic effects on health and survey for arsenic in groundwater in selected communes of Hanam province. Volume I: Test for arsenic in the groundwater tube wells in three communes Hoahau, Bode, Vinhtru of Hanam province*. NIOEH. Hanoi. Vietnam.

Nguyen, V. A., Bang, S., Viet, P. H., & Kim, K. W. (2009). Contamination of groundwater and risk assessment for arsenic exposure in Ha Nam province, Vietnam. *Environment International*, *35*(3), 466-472.

Nauges, C., & van de Berg, C. (2006). *Demand for piped and non-piped water supply services: Evidence from Sri-Lanka.* Working Paper 06.08.201. The French National Institute for Research in Agriculture (LEARNA). University of Toulouse. Toulouse. France.

Nauges, C., & Strand, J. (2007). Estimation of non-tap water demand in Central American cities. *Resource and Energy Economics*, *29*(3), 165-182.

Smith, A. H., Lingas, E. O., & Rahman, M. (2000). Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. *Bulletin of the World Health Organization*, *78*, 1093-1103.

Tran, T.K., & and Ross, W. (2009). Assessing arsenic contamination awareness of groundwater dependent residents in the Hanoi area. *Vietnam. Environment and Natural Resources Journal, 7*(1).

UN [United Nations]. 2001. *Synthesis report on Arsenic in drinking water*. WHO. Geneva, Switzerland.

UNICEF [United Nations Children's Fund]. (2001). *Report on investigated results for arsenic groundwater level in Hanoi city.* UNICEF Vietnam. Hanoi. Vietnam.

WB [World Bank]. (2003). *Fighting Arsenic: Listening to rural communities: Willingness to pay for arsenic-free, safe drigking water in Bangladesh.* WB, Washington D.C.

WHO [World Health Organization]. (2001). *Arsenic in drinking water. Fact sheet No. 210 (revised)*. WHO. Geneva. Switzerland.

Whittington, D., Lauria, D. T., Choe, K., Hughes, J. A., Swarna, V., & Wright, A. M. (1993). Household sanitation in Kumasi, Ghana: a description of current practices, attitudes, and perceptions. *World Development*, *21*(5), 733-748.

Whittington, D., Briscoe, J., & Mu, X. (1987). *Willingness to pay for water in rural areas: Methodological approaches and application in Haiti.* Wash field report No. 213. US Agency for International Development. Washington DC. USA.

Nauges, C., & Whittington, D. (2009). Estimation of water demand in developing countries: An overview. *The World Bank Research Observer*, *25*(2), 263-294.

Yuan, Y., Marshall, G., Ferreccio, C., Steinmaus, C., Selvin, S., Liaw, J., ... & Smith, A. H. (2007). Acute myocardial infarction mortality in comparison with lung and bladder cancer mortality in arsenic-exposed region II of Chile from 1950 to 2000. *American journal of epidemiology*, *166*(12), 1381-1391.

Vo, T.D., Huynh, V.K., Nguyen, M.H., & Nguyen, V.C. (2017). *Drinking water options in the context of arsenic contamination in the Vietnamese Mekong Delta.* EEPSEA Research Report No. 2017-RR4. Economy and Environment Program for Southeast Asia, Laguna, Philippines.