

Assessing Arsenic Contamination Awareness of Groundwater Dependent Residents in the Hanoi Area, Vietnam

การประเมินค่าการรับรู้การปนเปื้อนสารหนูของผู้อยู่อาศัยที่ใช้น้ำบาดาล
ในเมืองฮานอย ประเทศเวียดนาม

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Abstract

Various levels of arsenic have been found in the groundwater in the Hanoi area for the past 10 years. In some areas, arsenic levels are extremely above the standard level of drinking water. There is a large scale threat of arsenic poisoning in the Hanoi area and the risk is high because residents still use arsenic-contaminated water for their daily consumption with little or no treatment. The objectives of this study are to assess knowledge of residents regarding arsenic contamination, and to determine the relationship between arsenic knowledge and respondent's socio-economic and demographic characteristics. A household questionnaire interview was used to assess a respondent's knowledge regarding fundamental concerns about arsenic contamination problem. Three communes with low, medium and high arsenic levels in the groundwater were selected. This study found that awareness of residents in the three areas was low. Location, gender, occupation, household annual income and the level of education significantly influenced resident's knowledge about arsenic contamination. Farmer, laborer, people with a low income and education, and women had the lowest levels of awareness. These findings would be useful for the government in preventing and mitigating arsenic poisoning in specific high arsenic risk areas and in groups such as farmer, laborer, woman, and people with a low income and education..

Keywords: arsenic contamination/ awareness/ Hanoi, Vietnam/mitigation/education.

บทคัดย่อ

น้ำบาดาลในเมืองฮานอยมีสารหนูปนเปื้อนหลายระดับมานานกว่าสิบปี ในบางพื้นที่ ระดับการปนเปื้อนของสารหนูมากกว่าระดับมาตรฐานสำหรับน้ำดื่ม มีการแพร่กระจายของการปนเปื้อนสารหนูในเมืองฮานอยเป็นบริเวณกว้างและอัตราความเสี่ยงสูง เนื่องจาก ผู้อยู่อาศัยยังคงใช้น้ำที่มีการปนเปื้อนของสารหนูเพื่อบริโภคในชีวิตประจำวัน โดยมีการบำบัดเพียงเล็กน้อย หรือปราศจากการบำบัดวัตถุประสงค์ของการศึกษารั้งนี้ เพื่อประเมินการรับรู้ของคนในพื้นที่เกี่ยวกับการปนเปื้อนของสารหนู และเพื่อหาข้อสรุปถึงความสัมพันธ์ระหว่างความรู้ในเรื่องสารหนูและปฏิกิริยาโต้ตอบเชิงเศรษฐกิจและสังคมและลักษณะพื้นฐานประชากร แบบสอบถามใช้เพื่อประเมินความรู้ของผู้ให้สัมภาษณ์เกี่ยวกับความรู้พื้นฐานเรื่องสารหนู กลุ่มตัวอย่างมีทั้งหมดสามกลุ่มแบ่งตามระดับการปนเปื้อนของสารหนูในระดับน้ำบาดาล ระดับน้อย ระดับปานกลาง และระดับสูงตามลำดับ จากการศึกษาพบว่า ที่อยู่อาศัย เพศ อาชีพ รายได้ต่อปีและระดับการศึกษา ทั้งหมดนี้มีอิทธิพลต่อการรับรู้เกี่ยวกับการ

คำสำคัญ: การปนเปื้อนของสารหนู/ การรับรู้/ เมืองฮานอย/ ประเทศเวียดนาม/ การลดระดับ/ การศึกษา

1. Introduction

Along with an increase in groundwater usage for domestic consumption in recent decades, the concern of safe drinking water has become an issue due to the reality of chemical contamination and its adverse impacts on human health. One of the greatest concerns in groundwater is the presence of arsenic found since the 1990s. Indeed, a major cause of poisoning in human society with millions of poisoned persons is arsenic. For instance, in Bangladesh, there are between 37 and 57 million people suspected of being affected by drinking water contaminated with arsenic. Of these, millions are suffering from arsenicosis diseases such as skin lesions, skin pigmentation disorders, reproductive disorders and cancers (Madajewicz *et al* 2007, Paul 2004, Lindberg *et al* 2008, WHO 2001a). Arsenic appears in groundwater sources in almost every region in the world: Asia (Bangladesh, India, Vietnam, Cambodia, China, Taiwan, Thailand and Korea); the Americas (the USA, Chile, Argentina); Europe (Netherland, Russia); Australia (Bibi *et al* 2007, Madajewicza *et al* 2007, Tetsuro *et al* 2005, Thudiyil *et al* 2007, Naidu *et al* 2006, O'Shea *et al* 2007, Smedley 2003). Recently, the danger of arsenic to human health is being spread among communities through public media such as television, radio, internet and newspaper. However, many regions, mostly in developing countries, residents are still using unsafe water sources with arsenic concentration over 0.01 mg/L introduced by the World Health Organization (WHO) (WHO 2001b). As a result, millions of people are suffering arsenic poisoning. Due to the delayed health effects, poor reporting and low understanding as well as improper awareness in many regions, health effects caused by arsenic poisoning are unclear and not well documented. In addition to the toxicity and the wide-spread occurrence of arsenic, groundwater usage is rapidly increasing to meet rising water demands, especially for domestic consumption. Furthermore, with a lack of clean water systems, low quality or insufficient education programs among communities, arsenic contamination will remain a persistent threat to human health for the next decades.

Arsenic contamination in the groundwater in the Hanoi area

Hanoi is located in Northeast Vietnam, 21°2' N, 105°51' E. It lies on the Red River Delta and is 15-20 meters above sea level. Hanoi covers an area of 3,300 km² with 9 urban districts, two cities and 18 suburban districts with a population of 6.2 million people (in 2008).

The arsenic concentrations in groundwater in the Hanoi area vary from 1 to 3050 $\mu\text{g/L}$ (the average is roughly 159 $\mu\text{g/L}$), that is remarkable higher than the WHO guidelines for drinking water of 10 $\mu\text{g/L}$. In some high arsenic contaminated areas, especially in the south of the city, the average arsenic level is about 430 $\mu\text{g/L}$ (Berg *et al* 2001). The arsenic concentrations in the suburban areas in Hanoi city range from 0.1 to 330 $\mu\text{g/L}$, and 40% of samples exceed 10 $\mu\text{g/L}$ (Tetsuro *et al* 2005). In some locations, the arsenic concentration in raw groundwater is 300 times higher than the maximum concentration level recommended by the WHO (EAWAG 2001). Yet so far, no disease symptom has been diagnosed in the Hanoi area. This could possibly be explained by the fact that arsenic contaminated groundwater has been used as drinking water for just several years that accumulated arsenic amount in the inhabitant's body is not enough to expose arsenic poisoning clearly. Compared to arsenic poisoning problem in Bangladesh, Vietnamese people have a better nutrition than Bangladesh and this could reduce the time of exposure of arsenic poisoning (Tetsuro *et al* 2005). And the genetic characteristic is also one possible factor that might somehow influence exposure time. Additionally, withdrawn groundwater is usually stored for an extended period to remove fishy smell of irons before using and is filtered by sand filter system that can reduce arsenic compounds in water (Pham 2003). All of these reasons might explain the delay of arsenic poisoning in Vietnam (WHO 2005).

The threat of chronic arsenic poisoning in this area is a reality. However, little is known about the impact of arsenic poisoning on human health in the Hanoi area due to a lack of financial investment and an insufficient attention from government and the domestic scientific world. Furthermore, Hanoi is growing as a result of rapid urbanization and economic development. The supply of clean water can't meet the growing demand for water. Therefore, the number of people accessing arsenic contaminated water is continuing to increase. Hanoi aims to meet the Vietnam Development Goals with a target of 85% and 100% of urban population accessing clean water by the year 2010 and 2015 respectively (World Bank 2004). It will be a challenge for Hanoi to reach these goals. The best way to prevent arsenic poisoning is to have a proper understanding about this issue and to apply preventive measures among the communities.

In fact, many studies about arsenic contamination have been conducted recently by scientists from various fields such as hydrogeology, biochemistry and public health. However, the social aspect in terms of arsenic contamination awareness among the residents in the Hanoi area is rarely considered. The local and central governments have been spreading knowledge related to arsenic contamination to human health. However, the question to what the real awareness among the residents is in the contaminated areas has not been properly answered yet. This study seeks an answer to this question. Furthermore, the study ambitiously determines the relationship between socio-economic and demographic characteristics and arsenic contamination knowledge. The findings would be useful for the arsenic preventive educational programs focusing on specific area and group.

2. Methodology

The study area

The study areas are three arsenic contaminated communes that represent low arsenic level (lower than 50µg/L), medium arsenic level (50-100 µg/L) and high arsenic level (higher than 100µg/L). Furthermore, the study areas have no access to a clean water supply. Three communes satisfied requirements of the study are: the Thuongcat commune representing low arsenic level; the Dinhcong commune (medium arsenic concentration); and the Sondong commune (high arsenic concentration) (Berg *et al* 2008).

Sample size

Yamane formula was used to calculate sample size (Israsel 2003). Derived from 11920 households of the study area, and the precision level of 95%, the calculated sample size is 387 households. However, because some missing samples and outliers that can be happened, 401 households were interviewed.

Data collection

A structured interview method was used to interview 401 households. Data collection was conducted within a four week period in Hanoi. Five students of the Faculty of Environment, Phuongdong University were trained for collecting data for three days.

Households were randomly selected based on the number of cluster of the commune. In each selected household, an adult individual (over 18 years old) was randomly interviewed. Time for interviewing one respondent is approximately 30 minutes.

The questionnaire contains two sections: (1) the evaluation of respondent knowledge regarding the arsenic contamination problem, symptoms and diseases of arsenic poisoning, time of arsenic poisoning exposure and the preventive arsenic poisoning measure with 9 questions; and (2) the determination of respondents' socio-demographic characteristics. Seven factors are involved in this section: location, household size, gender, age, the level of education, occupation and household annual income.

Arsenic score ranking

To determine respondent's knowledge about arsenic, each answer is weighted from zero to three points (table 1). In the first question, zero point is given to those who have never heard about arsenic contamination, three points are given to those who knew about that issue more than 3 years ago. For question 2, three points is awarded for the correct answer that humans cannot identify arsenic in water through human senses; zero point is given for incorrect answer. Question 3 aims to know where is the source of arsenic in groundwater due to respondent's point of view. The first answer is related to

mystery, the intervention deity, curse and land owner's moral or behavior because Vietnamese people still strongly believe supernatural elements due to their traditions and rituals, especially things relate to diseases. Three points are given to correct answer that arsenic occurs in groundwater naturally that is consistent with common opinion about the source of arsenic (Berg *et al* 2001, 2007, 2008). With the question 4, three points are awarded for correct answer – arsenic poisoning is caused by drinking and cooking arsenic contaminated water. The purposes of question 6, 7, and 8 are to assess respondent's knowledge in term of symptoms and diseases related to arsenic poisoning. One, two and three point(s) is/are correspondingly awarded for one, two and three symptom(s) or disease(s). Question 6 and 8 regards to visible symptoms the cancers of exposure time. People develop some visible symptoms and cancer after a long time of arsenic poisoning usually more than five years and from 10 to 20 years, respectively (WHO 2001a). Therefore, three points are given for the answer that the development of visible symptoms of arsenic poisoning is more than three years. In some cases, cancer can be developed within five to nine years (Paul 2004), but these are not so common. Thereby the answer “more than 10 years” awards three points, “from five to nine years” gains two points; “from one to four years” is ranked as one point. The last question in this section concerns about arsenic removal methods that resident should know in order to prevent or mitigate arsenic contamination. One, two and three method(s) is (are) given one, two and three points, respectively. The maximum score derived from nine questions is 27.

Data analysis

All data was pretreated before analyzing. That is, household size was divided into two groups: group 1 (from 1-5 family members); and group 2 (over 5 family members). Age was categorized into three groups: group 1 (from 18-35 years old); group 2 (36-50 years old); and group 3 (over 50 years old). Occupation was divided into five groups: group 1 (farming); group 2 (labor); group 3 (business); group 4 (official); and group 5 (other). Level of education was ranked into four groups based on the number of year in school: group 1 (less than or equal 5 years); group 2 (6-9 years); group 3 (10-12 years); and group 4 (over 12 years). Household annual income was categorized into four groups: group 1 (less than or equal 30 millions VND); group 2 (over 30-60 millions VND); group 3 (over 60-90 millions VND); and group 4 (over 90 million VND).

Before analyzing, some preliminary data screening were performed to analyse the normal distribution of quantitative data, and to determine the outlier(s). The graphic method that is based on percentiles- *box and whiskers plot* – is used to determine the outlier. Eleven outliers were found and removed before analyzing data. Another assumption of the homogeneity of variance is also checked (Warner 2008, Babbie 2007).

Table 1 Questions, correct answers and allocated points regarding arsenic knowledge

Questions	Expected answers	Assigned points
1. When did you first hear about arsenic contamination in groundwater?	More than 3 years ago	
<input type="checkbox"/> Never		0
<input type="checkbox"/> Yes, less than one year ago		1
<input type="checkbox"/> Yes, within 1-3 years ago		2
<input type="checkbox"/> Yes, more than 3 years ago		3
2. If "YES", can you know arsenic in water by using some senses like taste, smell and eyesight?	Impossible to detect arsenic in water by human senses	
<input type="checkbox"/> Yes, I know how to identify it by using my senses		0
<input type="checkbox"/> No, I don't have this ability		1
<input type="checkbox"/> No, It is impossible to know arsenic in water by human senses		3
3. Where does arsenic in groundwater in your village (tube-wells) come from?	Arsenic occurs in groundwater naturally	
<input type="checkbox"/> Mystery (Ghost, related to land owner's morals or behavior)		0
<input type="checkbox"/> I don't know		0
<input type="checkbox"/> From human activities (industry, agriculture)		1
<input type="checkbox"/> It exists in groundwater naturally in the soil and rock.		3
4. What is the cause(s) of arsenic poisoning?	Both drinking and cooking	
<input type="checkbox"/> I don't know		0
<input type="checkbox"/> Bathing and washing of an arsenic contaminated water		1
<input type="checkbox"/> Drinking and Cooking of an arsenic contaminated water		3
5. List all visible symptoms of arsenic poisoning as many as you can	Darkening of skin on palms, dark spots on the body, keratosis, lesion.	
<input type="checkbox"/> Don't know		0
<input type="checkbox"/> 1 symptom		1
<input type="checkbox"/> 2 symptoms		2
<input type="checkbox"/> ≥ 3 symptoms		3
6. How long does arsenic poisoning take to develop visible symptoms?		
<input type="checkbox"/> Don't know		0
<input type="checkbox"/> ≤ 1 year		1
<input type="checkbox"/> 1-3 years		2
<input type="checkbox"/> > 3 years		3
7. List all diseases that are caused by arsenic poisoning as many as you can.	Keratosis, gangrenous ulcer, skin, lung, liver and bladder cancer.	
<input type="checkbox"/> Don't know		0
<input type="checkbox"/> 1 disease		1
<input type="checkbox"/> 2 diseases		2
<input type="checkbox"/> ≥ 3 diseases		3
8. How long does arsenic poisoning take to develop cancer?		
<input type="checkbox"/> Don't know		0
<input type="checkbox"/> 1-4 years		1
<input type="checkbox"/> 5- 9 years		2
<input type="checkbox"/> ≥ 10 years		3
9. List all the arsenic removal methods as many as you know	Sand filter, Reverse Osmosis, Solar Oxidation, Chlorination, etc.	
<input type="checkbox"/> Don't know		0
<input type="checkbox"/> 1 method		1
<input type="checkbox"/> 2 methods		2
<input type="checkbox"/> ≥ 3 methods		3

In analyzing the data, the descriptive statistics is used to determine the arsenic knowledge of each socio-economic and demographic group. The relationships between respondents' arsenic knowledge and their household's socio-demographic characteristics are also analysed by bivariate analysis. That is, Independent Sample T test is used to compare the mean between two different groups; ANOVA is used for comparing more than two different groups. The Tukey HSD test also used for further determination the relationship within groups, if have. Nonparametric analysis like Kruskal-Wallis is also used for analyzing the relationship of independent variables and arsenic knowledge in which the assumption of parametric variables are violated.

3. Results and discussions

Respondent's arsenic contamination knowledge

The descriptive results of all group levels derived from seven factors regarding arsenic knowledge are showed in table 2. The medium arsenic contaminated area (urban) has the highest knowledge score (Mean =10.98). While the average score of the low and high arsenic contaminated area are 9.32 and 8.75, respectively. This finding is not consistent with the assumption that the high arsenic contaminated area should have more knowledge than the lower ones. Additionally, respondents who are over 50 years old have the highest knowledge compared to the other age groups. The age group (36-50) has the lowest knowledge score (8.99). Famer group was found to have the lowest knowledge among six occupational groups with an average score of 7.64. Meanwhile, official group has the highest knowledge score (13.15). Apparently, knowledge scores increase from the low educational level to the higher ones. In other words, a higher education level has higher knowledge. The average knowledge scores among four household annual income groups are different (table 2). The highest income group owns the highest knowledge score, while the second lowest income group (30-60 million VND) gain the lowest knowledge.

In summary, there are no case of 390 households answered correctly all 9 questions. Most of groups gains from 9 to 13 scores out of a possible 27 scores. Hence, residents' arsenic knowledge is very low. Furthermore, most respondents were unable to answer the arsenic poisoning symptoms and diseases.

The relationship between socio-economic and demographic factors, and arsenic knowledge

Arsenic knowledge of each socio-economic and demographic group was presented and discussed above. Hence, the answer for the question whether these socio-economic and demographic factors significantly relate to arsenic knowledge is determined through bivariate analysis.

Table 2 Household socio-economic and demographic factors, and arsenic knowledge

Variables	N	Mean	Standard Deviation
Commune			
Low arsenic contaminated area	127	9.32	5.607
Medium arsenic contaminated area	129	10.98	5.330
High arsenic contaminated area	134	8.75	4.594
Household size			
1-5 people	336	9.85	5.209
>5 people	54	8.56	5.476
Gender			
Male	182	10.31	5.151
Female	208	9.12	5.302
Age			
18-35 years old	119	9.97	4.866
36-50 years old	138	8.99	5.629
>50 years old	133	10.12	5.165
Occupation			
Farming	112	7.64	4.755
Labor	76	8.75	4.828
Business	71	9.62	5.994
Official	62	13.15	4.851
Others	80	11.26	5.238
Level of education (year in school)			
≤5	39	7.41	6.112
6-9	142	7.88	4.901
10-12	136	10.53	4.662
>12	73	12.78	4.650
Household annual income (in VND)			
≤30 millions	134	9.22	4.510
>30-60 millions	147	8.65	5.760
>60-90 millions	71	11.37	4.966
>90 millions	38	12.08	4.868

It was found that the three communes are statistically significant different regarding arsenic knowledge at the 0.05 significance level ($F=6.556$, $p=0.002$) (table 3). Further, through the Tukey HSD test, arsenic scores of both the low and high arsenic contaminated areas do differ from the medium ones (p values <0.05). The low arsenic contaminated area has a higher arsenic knowledge score than the high ones (9.32 compared to 8.75), though, this difference is not statistically significant ($p>0.05$). Hence, the resident's knowledge bases on the location rather than the arsenic pollution level. Household size does not significantly influence on respondent arsenic knowledge whatever household has small or big size ($t=1.688$, $p>0.05$). By contrast, gender does influence on respondent knowledge at the 0.05 significance level ($t=2.236$, $p<0.05$). That is, males have more arsenic knowledge than females. This study found that there are no differences among the three age groups in terms of arsenic knowledge ($F=1.829$, $p>0.05$). Therefore, the found differences among the three age groups are not significant. Occupation was found to have a significant influence on resident's arsenic knowledge ($F=14.044$, $p<0.05$). Furthermore, the Tukey HSD test indicates that farmer and laborer group are significantly different from the official and others group regarding arsenic contamination knowledge ($p<0.05$). No significant differences were found among farmer, laborer and businessman group; and between official and other

group. Through the Krusal-Wallis testing, this study found that the level of education and household annual income do significantly influence on resident's arsenic knowledge at the 0.05 significance level.

Table 3 Results of bivariate analysis

Variables	Testing method	Test results
Location	F- test	6.556 ($p=.002$)
Household size	T-test	1.688 ($p=.092$)
Gender	T-test	2.236 ($p=.026$)
Age	F-test	1.829 ($p=.162$)
Occupation	F-test	14.044 ($p=.000$)
Level of education	Chi-square test	49.341 ($p=.000$)
Household annual income	Chi-square test	20.939 ($p=.000$)

4. Conclusion and recommendation

Arsenic contamination in groundwater had been found for some 10 years in the Hanoi area. Recently, this problem has been warned by researchers and the government authorities. However, residents still use the contaminated water for their daily consumption because of not being other water sources. This empirical study had assessed the knowledge of residents concerning to the understanding about arsenic contamination, the causes and effects of arsenicosis diseases and preventive measures. The relationships between the resident's arsenic knowledge and socio-economic and demographic characteristics are also determined.

The findings of this study explore that the arsenic contamination knowledge in the three surveyed areas is insufficient correlating to the level of arsenic contamination, especially in the rural area. Moreover, the misunderstandings about arsenic with organic matters and iron in water regarding the determination of arsenic in water are widely acknowledged among residents. Many of residents informed that they can detect arsenic in water through smelling and eyesight. Also, many residents were misunderstood about arsenic symptoms and diseases with some popular water related diseases like diarrhea, scabies or dermatophyte. These findings indicate that the local government was not successful in disseminating arsenic contamination knowledge to residents, especially those in the high arsenic contaminated area. These findings would be very useful for the Hanoi government in raising residents' arsenic knowledge regarding the arsenic level in groundwater, in determining arsenic contamination with other caused water pollution and in understanding the negative impacts of arsenic contamination to human health.

This study found that arsenic knowledge is statistically significantly related to the level of education, household annual income, occupation, location and gender. That is, the low educated people, the poor, farmer, laborer, women and residents in the high arsenic risk area owns low arsenic contamination knowledge than others. On the contrary, household size and age do not significantly influence on arsenic knowledge.

Corresponding to supply clean water programs, the educational campaigns in providing sufficient arsenic contamination knowledge to residents in the contaminated area is strongly needed to be intensified regarding the causes and effect of arsenic poisoning, and the arsenic poisoning preventive measures, and focuses on specific groups and area including the poor, women, the low educated people and the high arsenic contaminated area. Furthermore, in order to prevent or mitigate a wide scale of arsenic poisoning in the Hanoi area, the Hanoi government institutions and researchers should pay much attention focusing on the use and management of groundwater in Hanoi towards sustainability.

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