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ORIGINAL PAPER

Current status of arsenic exposure and social implication in the Mekong River basin of Cambodia

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Abstract To evaluate the current status of arsenic exposure in the Mekong River basin of Cambodia, field interview along with urine sample collection was conducted in the arsenic-affected area of Kandal Province, Cambodia. Urine samples were analyzed for total arsenic concentrations by inductively coupled plasma mass spectrometry. As a result, arsenicosis patients ($n = 127$) had As in urine (UAs) ranging from 3.76 to 373 $\mu g\ L^{-1}$ (mean $= 78.7 \pm 69.8$ $\mu g\ L^{-1}$; median $= 60.2$ $\mu g\ L^{-1}$). Asymptomatic villagers ($n = 108$) had UAs ranging from 5.93 to 312 $\mu g\ L^{-1}$ (mean $= 73.0 \pm 52.2$ $\mu g\ L^{-1}$; median $= 60.5$ $\mu g\ L^{-1}$). About 24.7 % of all participants had UAs greater than 100 $\mu g\ L^{-1}$ which indicated a recent arsenic exposure. A survey found that females and adults were more likely to be diagnosed with skin sign of arsenicosis than males and children, respectively. Education level, age, gender, groundwater drinking period, residence time in the village and amount of water drunk per day may influence the incidence of skin signs of arsenicosis. This study suggests that residents in Kandal study area are currently at risk of arsenic although some mitigation

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has been implemented. More commitment should be made to address this public health concern in rural Cambodia.

Keywords Arsenic · Urine · Social implication · Arsenicosis patient · Asymptomatic villager · Cambodia

Introduction

Chronic exposure to arsenic-rich groundwater is a major public health issue in many parts of the developing countries including Cambodia. Arsenic contamination in Cambodian drinking water sources was detected during the national drinking water quality assessment, jointly conducted by the Ministry of Rural Development and the Ministry of Industry, Mines and Energy between 1999 and 2000 (Feldman et al. 2007). To date, high arsenic concentrations in Cambodian groundwater have been successively reported (Polya et al. 2005; Stanger et al. 2005). For instance, groundwater arsenic concentrations in the Mekong delta of Cambodia ranged from below the limit of detection up to about 900 $\mu g\ L^{-1}$ with about 54.0 % of all the samples collected exceeding the WHO's drinking water quality guideline value of 10.0 $\mu g\ L^{-1}$ (Sthiannopkao et al. 2008). In particular, arsenic concentrations in the groundwater in Kandal Province ranged from 6.64 to 15.4 $\times$ 10^2 $\mu g\ L^{-1}$ with the average and median concentrations of 552 and 353 $\mu g\ L^{-1}$, respectively (Luu et al. 2009). Concurrently, our previous study reported that arsenic concentration in groundwater consumed by local residents of Preak Russey Village, Kampong Kong Commune, Koh Thom District, Kandal Province, ranged from 247 to 18.4 $\times$ 10^2 $\mu g\ L^{-1}$ with a mean of 846 $\pm$ 298 $\mu g\ L^{-1}$ (Phan et al. 2010). Our cross-sectional health risk assessment of inorganic arsenic intake of people residing in the Mekong River basin of Cambodia revealed that residents in the Kandal (98.7 %) and Kratie (13.5 %) province study areas were confronted to deleterious arsenic in groundwater (Phan et al. 2010). As a result, arsenicosis patients have been discovered among the exposed populations in the affected areas of Kandal and Prey Veng provinces (Sampson et al. 2008; Mazumder et al. 2009; UNICEF 2009; Hashim et al. 2013). In response to the discovery of arsenic in Cambodian drinking water source, the Royal Government of Cambodia has established an interior subcommittee to regulate the arsenic concentration in drinking water. Cambodian drinking water standard was developed in which the permissible limit of arsenic was set up to be 50.0 $\mu g\ L^{-1}$ as low as other developing countries (Sampson et al. 2008). National well testing campaign was consequently conducted in a number of provinces to identify the arsenic-affected areas using arsenic field test kit. Concurrently, several non-governmental organizations (NGOs) and local authorities have developed information, education and communication (IEC) materials to educate the effected communities about risks of consuming arsenic-rich groundwater. In addition, educational programs for school children were developed and implemented in several schools in the highly affected areas. Wells shown arsenic concentrations higher than Cambodian standard were painted red as practiced in Bangladesh and elsewhere. Red wells indicated to community members that water from the well is not safe for drinking. That kind of educational effort was partially successful in the communities which often followed the recommendations regarding to water quality and suspect of suffering from drinking arsenic-rich groundwater (Sampson et al. 2008). However, the positive impacts of those initiatives were significantly reduced due to successive installation of a large number of new tubes well without arsenic testing in the arsenic high risk areas. Recently, arsenic removal units have been installed in several affected communities in Kandal, Prey Veng and Kampong Cham provinces through collaborative projects (AISC 2014; German et al. 2014; Kang et al. 2014). Each unit was anticipated to provide arsenic-safe water for approximately 200 households. However, educational programs are required to mobilize people for collecting arsenic-safe water from the units (Kim et al. 2011). Therefore, the present study aimed to (1) determine the distribution of arsenic concentration in urine of residents exposed to arsenic-rich groundwater in the Mekong River basin of Cambodia; (2) evaluate the current status of arsenic exposure among the exposed populations, (3) determine factors influenced on the development of skin signs of arsenicosis and arsenic concentration in urine and (4) investigate social implication in the arsenic-affected areas in the Mekong River basin of Cambodia.

Materials and methods

Study area and population

A national well testing campaign was conducted in some provinces along the Mekong River and Tonle Sap Great Lake using arsenic field test kit, after high arsenic concentration was reported in Cambodian shallow groundwater. Among the tested wells, 35.0 % of the tube wells in Kandal, 48.0 % in Kampong Cham, 19.0 % in Prey Veng, 13.0 % in Kratie, 9.00 % in Phnom Penh, 6.00 % in Kampong Chhnang and 3.00 % in Kampong Thom had arsenic concentrations higher than 50.0 μg L^{-1}, Cambodian drinking water quality standard (UNICEF 2009). Concurrently, clinical survey was conducted in the affected area of Kandal and Prey Veng provinces. In total, 279 people from six villages of Kandal and 32 people from three villages of Prey Veng were identified with suspected arsenicosis symptoms. Among those, 135 were women and 56 were children (UNICEF 2009). Leukomelanosis (raindrop pigmentation on skin) and nodular keratosis were commonly reported among the suspected cases (Mazumder et al. 2009). However, Gollogly et al. (2010) have recently reported that some skin cancer and severe ulcer were developed and amputation was required among the arsenicosis patients in rural Cambodia. The present study was conducted in the Tuol Svay Village (formerly known as Preak Russey Village), Kampong Kong Commune, Koh Thom District, Kandal Province of Cambodia, where most of arsenicosis cases have been reported (Fig. 1).

Field data collection

The present study was approved by the National Ethics Committee for Health Research (reference no. 114NECHR, 04/08/2011) under the Ministry of Health of the Royal Government of Cambodia. After informed consent was obtained, data were collected from respondents who were randomly selected from the village at the end of July and the beginning of August 2011. Volunteer participants were physically examined for arsenicosis signs and symptoms following the WHO's diagnostic procedure (WHO 2000). After physical examination, participants were interviewed by a questionnaire. First, respondents were asked to provide their demographic information including their name, home address, gender and age. Then, they were asked to provide their education levels and daily incomes. The respondents were also asked to provide their current smoking status and/or tobacco use, and they were then asked to provide the source of their drinking water in wet and dry seasons. Groundwater consumption status and option and the location of groundwater were also included in the questionnaire. The amount of water drunk per day, the period of drinking groundwater and the duration of living in the village were also collected. Finally, each participant was asked to sign the written consent after they provided all answers.

Urine sample collection and analyses

Following the interview, participants were requested to voluntarily provide their urine samples for their exposure assessment. Each spot urine sample was collected and stored in two different bottles, namely acid-cleaned polyethylene and sterile bottles. All urine samples were kept in an icebox during field work, after which the sterile bottles were delivered to the Institut Pasteur du Cambodge in the afternoon on the same day to determine the urinary creatinine concentrations, and the acid-cleaned polyethylene bottles were transferred to a freezer and stored at −20 °C until analysis. Urinary creatinine (UCre) was analyzed at the Institut Pasteur du Cambodge using picric acid (Roche Diagnostics, COBAS INTEGRA CREJ2) technique. An attempt has been made to develop our own analytical methods to determine the arsenic in urine. First, the frozen urine samples were allowed to thaw at room temperature. Then, 1.00 mL of urine was pipetted into a 15-mL acid-cleaned polyethylene centrifuge tube, after which 9.00 mL of diluted nitric acid (0.50 mol L^{-1}) was added. The tube was then centrifuged at 3000 rpm for 10 min, and after that, the resulting supernatant was filtered (0.2 μm) into a fresh tube. In parallel, the same urine sample was also digested with concentrated nitric acid (65 %) and hydrogen peroxide (30 %). Urine (0.20 mL) was pipetted into a 15-mL acid-cleaned polyethylene centrifuge tube, after which 0.50 mL of nitric acid and 1.00 mL of hydrogen peroxide were subsequently added. The tube was allowed to stand for 15 min prior to heating at 100 °C for 3 h in a heating block (TAITEC Dry Thermo Unit UTU-2C, Japan). The digestate was then diluted to 10 mL with

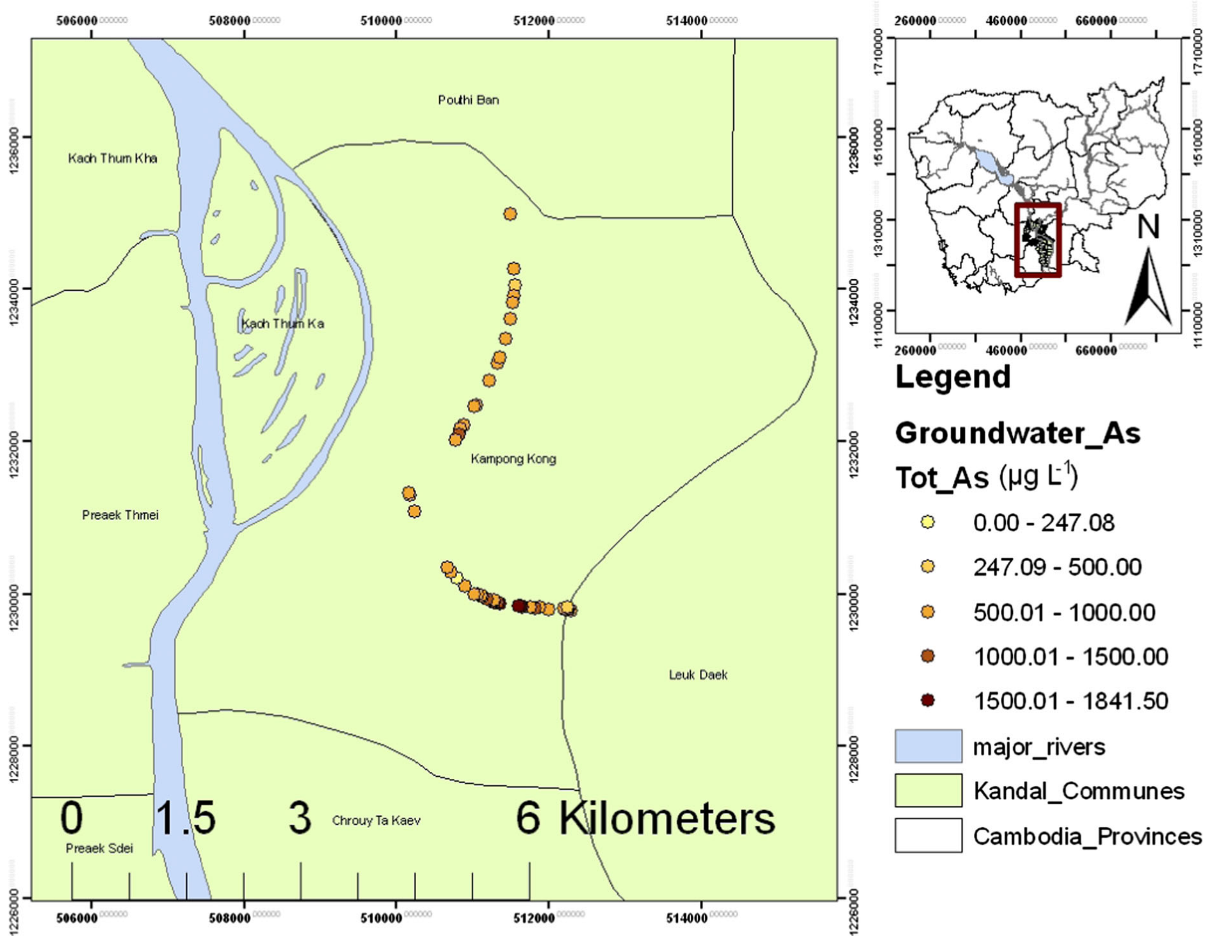

Fig. 1 Map of the study area. Adapted from Phan et al. (2010)

18.2 MΩ MilliQ deionized water and filtered (0.2 μm) into a fresh tube. All chemical measurements of total arsenic concentration were taken by inductively coupled plasma mass spectrometry equipped with Octopole Reaction System (ICP-MS, Agilent 7500ce, USA). Two replicates of each spot urine sample were randomly extracted and digested to verify the precision and accuracy of the instrument and analytical methods. Spiking of urine samples was conducted in low (10 μg L^{-1}), medium (20 μg L^{-1}) and high (50 μg L^{-1}) levels. Spiked urine was treated in the same manner as the sample to verify the accuracy and precision of the extraction and digestion methods. The recovery rate (RSD < 10 %) from the extraction and digestion of urine and spiked samples was in a good agreement with recommended values (90–110 %).

Data analyses

Data from urine extraction method have been reported and used for statistical analysis throughout this manuscript. All statistical data analyses were employed by SPSS for windows (version 16.0). Chi-square analyses were performed to verify the difference in arsenicosis diagnosed among males and females, children (aged ≤12 years) and adults (aged >12 years), well location (whether people share or they own the well) and current groundwater consumption (whether they consume groundwater or not). The strength of the correlation was measured by Phi and/or Cramer's V. Mann–Whitney's U test was applied to access the differences in the amount of the daily income and education levels, age, the period of drinking groundwater and the duration of living in the village between arsenicosis patients and asymptomatic villagers. Significance was considered in circumstance where $p < 0.05$.

Results and discussion

Characteristics of the study populations and social implication of arsenic exposure in Cambodia

The outcomes of field survey are presented in Tables 1 and 2. Among 246 participants, 8.90 % were children (aged $\leq$12 years). None of children were detected with arsenicosis symptoms. However, 131 were diagnosed with arsenicosis symptoms and 101 persons were women. Approximately 84.6 % of the total respondents could earn less than 8.00×10^3 KHR (USD 2.00) per day; among those, 43.9 % are arsenicosis patients; 14.6 % could earn from 8.00×10^3 KHR (USD 2.00) to 20.0×10^3 KHR (USD 5.00); and less than 1.00 % could earn from 20.0×10^3 KHR (USD 5.00) to 40.0×10^3 KHR (USD 10.0). About 42.3 % of all participants did not go to school; of those, 28.0 % were arsenicosis patients. Out of 131 arsenicosis patients, 54 went to primary school (grade 6 or less) and eight went to secondary school (grade 9 or less). Forty-eight patients smoked and/or used tobacco during field survey, and three persons previously smoked, but gave up before field survey. Out of all 82 smokers and/or tobacco users, 32 patients smoked less than five cigarettes per day; however, five patients smoked more than 20 cigarettes per day. About 52.80 % of all respondents shared well with their neighbors, of whom 27.2 % were arsenicosis patients. Although the residents in this study area have stopped drinking groundwater, 61.4 % of all respondents still used it for other purposes; 1.30 % used it for bathing; 8.60 % used it for washing clothes and/dishes; and the majority (90.1 %) used it for either bathing or washing. In dry season, 3.70 % of all respondents used rainwater, while 11.8 % went for piped water and 12.6 % took water from open well/pond. The majority (72.0 %) used water from various alternative sources (i.e., rainwater, piped water and open well/pond). In raining season, 6.10 % used rainwater; 1.20 % went to the open well/pond; and the majority (91.9 %) took water from various sources. About 39.4 % of all respondents, of whom 26.0 % were arsenicosis patients, drank 2 liters of water per day; the other 24.0 and 21.5 % drank about 1.50 and 1.00 L of water per day, respectively.

In order to investigate whether males and females differ on whether they were diagnosed for arsenicosis or not, a Chi-square statistic was used. Table 1 shows the Pearson Chi-square results and indicated that males and females were significantly different on whether they were diagnosed for arsenicosis

Table 1 Chi-square analysis of prevalence of diagnosing arsenicosis among gender, age group, location of tube well, other purpose of groundwater consumption and smoking status of residents

Variables	*n*	Asymptomatic	Arsenicosis	χ^2	*p*
Gender				8.39	0.004
Female	170	69	101		
Male	76	46	30		
Age groups				27.52	<0.001
Aged $\leq$12 years	22	22	0		
Aged >12 years	224	93	131		
Location of tube well				0.325	0.569
Share with others	130	63	67		
Well at home	116	52	64		
Other use of groundwater				2.99	0.084
No	95	51	44		
Yes	151	64	87		
Smoking status				2.17	0.338
No	160	80	80		
Yes, currently	80	32	48		
Yes, previously	6	3	3		

Table 2 Comparison of daily income, education level, age, groundwater drinking period, residency in village and amount of water drunk per day, As in urine and adjusted As in urine by creatinine between asymptomatic and arsenicosis

Variables	N	Median	Z	p
Daily income (USD)[a]			−0.96	0.335
Asymptomatic	115	1.00		
Arsenicosis	131	1.00		
Education level (y)[b]			−3.09	0.002
Asymptomatic	115	2.00		
Arsenicosis	131	1.00		
Age (y)			−5.12	<0.001
Asymptomatic	115	31.0		
Arsenicosis	131	46.0		
Groundwater drinking period (y)			−7.46	<0.001
Asymptomatic	115	10.0		
Arsenicosis	131	18.0		
Residency in village (y)			−4.9	<0.001
Asymptomatic	115	30.0		
Arsenicosis	131	39.0		
Amount of water drunk per day (L)			−3.9	<0.001
Asymptomatic	115	1.50		
Arsenicosis	131	2.00		
As concentration in urine (μg L^{-1})			−0.27	0.79
Asymptomatic	108	60.5		
Arsenicosis	127	60.2		
UAs_{adj} (ngAs mg^{-1} creatinine)			−1.91	0.056
Asymptomatic	108	72.5		
Arsenicosis	126	68.5		

[a] Daily income was, respectively, coded 1, 2, 3 and 4 as earned 8000 riels or less (earned USD 2 or less), earned 20,000 riels or less (earned USD 5 or less), earned 40,000 riels or less (earned USD 10 or less) and earned more than 40,000 riels (earned more than USD 10) groups

[b] Education levels, which were grouped as none, primary school or less (grade 6 or less), secondary school or less (grade 9 or less), high school or less (grade 12 or less) and beyond high school (beyond grade 12), were coded 1, 2, 3, 4 and 5, respectively

($\chi^2 = 8.39$, $df = 1$, $n = 246$, $p < 0.05$). Females were more likely than expected under the null hypothesis to be diagnosed for arsenicosis than males. Likewise, female adults (aged >12 years) were more likely to be diagnosed for arsenicosis than male ones ($\chi^2 = 7.40$, $df = 1$, $n = 224$, $p < 0.05$). This might be because Cambodian women are culturally and socially a housekeeper who spend more time at home than men working outside their village. The more they stay in the village, the more they expose to arsenic through consuming arsenic contaminated foodstuffs, which have been reported by Phan et al. (2013). Further analyses revealed that female adult patients drank significantly less amount of water than male ones (Mann–Whitney's U test, $p < 0.05$). Males might ingest less amount of arsenic than females because they could have an access to arsenic-free water at their workplaces. The difference in children and adults on whether or not they were diagnosed arsenicosis was also investigated. Adults (aged >12 years) were more likely to be diagnosed for arsenicosis than children (aged ≤12 years) ($\chi^2 = 27.52$, $df = 1$, $n = 246$, $p < 0.001$) (Table 1). However, arsenicosis was not significantly different in whether respondents shared a well with their neighbors or they had it at home ($\chi^2 = 0.325$, $df = 1$, $n = 246$, $p = 0.569 > 0.05$).

Likewise, arsenicosis was not significantly associated with whether or not respondents consumed groundwater for other purposes rather than drinking ($\chi^2 = 2.99$, $df = 1$, $n = 246$, $p = 0.084 > 0.05$) (Table 1). Table 2 shows that arsenicosis patients are not significantly different from the asymptomatic villagers in making their daily income (Mann–Whitney's U test, $p > 0.05$). However, arsenicosis patients are significantly different from the asymptomatic villagers in their educational levels. The inspection of the two group median indicates that the median of educational level of arsenicosis patients was significantly lower than that of their asymptomatic villagers. Arsenicosis patients and their asymptomatic villagers also significantly differ in their ages, the period of drinking groundwater, the amount of water drunk per day and their duration of living in the village (Mann–Whitney's U test, $p < 0.05$). A comparison indicates that arsenicosis patients are significantly older and live longer in the village than their asymptomatic villagers. The arsenicosis patients also drink groundwater longer period and higher amount than their asymptomatic villagers (Table 2). This finding is consistent to our previous report which showed that health risk of arsenic exposure and arsenic accumulation of Cambodian residents was induced by exposure duration, ingestion rate and age (Phan et al. 2010). Hassan et al. (2005) reported patients' experience of ostracism, difficulties in daily activities in Bangladesh and the social issues between patients and unaffected populations. However, our field survey found that there was a little tendency for the neighbor villagers to avoid the arsenicosis patients from Toul Svay Village at the beginning of the outbreak. The increased distance between arsenicosis patients with their relatives, friends and villagers is currently not found. In addition, the discrimination and behavior toward to arsenicosis patients are currently negligible.

Arsenic in urine of the exposed inhabitants in rural Cambodia

As in urine (UAs) of the study participants is presented in Table 3. In fact, two procedures have been developed to analyze As in urine samples, namely extraction and digestion. The reliability of the repeated measurements of As in urine digested with concentrated nitric acid and hydrogen peroxide and extracted with diluted nitric acid could be statistically verified (Wilcoxon's signed-rank tests, $p > 0.05$). Simple regressions were applied to investigate how well the first batch of analyses could be predicted by the second ones ($R^2 = 0.98$) and how well urine extract could predict urine digest ($R^2 = 0.98$). Arsenicosis patients ($n = 127$) had UAs ranging from 3.76 to 373 μg L^{-1} (mean = 78.7 ± 69.8 μg L^{-1}, median = 60.2 μg L^{-1}). Asymptomatic villagers ($n = 108$) had UAs ranging from 5.93 to 312 μg L^{-1} (mean = 73.0 ± 52.2 μg L^{-1}, median = 60.5 μg L^{-1}) (Table 3). UAs in the present study were consistent with a previous study conducted in Preak Russey Village which reported mean UAs of the positive ($n = 87$) and negative ($n = 55$) skin signs of arsenicosis 72.4 ± 59.4 and 63.4 ± 45.1 μg L^{-1}, respectively (Huang et al. 2014). However, total UAs_{adj} (Table 3) was lower than that of the Kratie resident exposed to arsenic-rich groundwater which ranged from 40.9 to 11.2×10^2 ngAs mg^{-1} creatinine with mean of 201 ngAs mg^{-1} creatinine (Kubota et al. 2006). A comparison (Table 2) revealed that UAs of the arsenicosis patient was not significantly different from that of asymptomatic villagers (Mann–Whitney's U test, $p > 0.05$). About 24.7 % of all participants had UAs greater than 100 μg L^{-1}, indicating the recent arsenic exposure (ATSDR 2007). Out of 108 asymptomatic villagers, 24.1 % had UAs greater than 100 μg L^{-1}, whereas 25.2 % of arsenicosis patients ($n = 127$) did. The measurement of UAs is generally accepted as the most reliable biomarker of the recent arsenic exposure (ATSDR 2007). The outcomes of the present study suggest that either arsenicosis patients or asymptomatic villagers in the study area are currently exposed to arsenic although some mitigating measures have been undergone. A strategic action plan developed by the Royal Government of Cambodia (AISC 2007) gave a focus on the direct arsenic contamination in groundwater, but it did not take other consequences of consuming arsenic-rich groundwater into account. In fact, a number of studies have reported arsenic concentrations in paddy soils irrigated with arsenic-rich groundwater (Phan et al. 2013; Seyfferth et al. 2014). Concurrently, paddy rice in the arsenic-affected areas in the Mekong River basin of Cambodia has been reported to contain deleterious arsenic concentrations which can pose potential health effects to consumers (Phan et al. 2013, 2014; O'Neill et al. 2013; Wang et al. 2013; Seyfferth et al. 2014). It is suggestive that further mitigation effort should consider arsenic in rice as an additional source of arsenic intake among the exposed populations in rural Cambodia. Two

Table 3 Summary of As concentration in urine (μg L^{-1}), urinary creatinine (mg L^{-1}) and adjusted As concentration in urine by creatinine (ngAs mg^{-1} creatinine) of arsenicosis patients and asymptomatic villagers

Statistics	Asymptomatic			Arsenicosis			All		
	UAs	UCre	UAs_{adj}	UAs	UCre	UAs_{adj}	UAs	UCre	UAs_{adj}
Mean	73.0	944	91.7	78.74	10.6×10^2	78.0	76.7	10.1×10^2	84.2
Median	60.5	843	72.5	60.2	978	68.5	60.5	929	70.3
SD	52.2	622	59.5	69.8	695	42.8	64.1	661	51.3
Min	5.93	103	20.5	3.76	111	5.02	3.76	103	5.02
Max	312	31.0×10^2	439	373	40.6×10^2	226	373	40.6×10^2	439

SD standard deviation, *Min* minimum, *Max* maximum, *UAs* arsenic concentration in urine, *UCre* urinary creatinine, UAs_{adj} adjusted As concentration in urine by creatinine

groups of participants were characterized using a cutoff point of UAs of 100 μg L^{-1}. Gender, location of tube well, other use of groundwater, arsenicosis symptoms and smoking status of inhabitants are not significantly different among those having UAs $\leq$ 100 μg L^{-1} and those who had UAs > 100 μg L^{-1} (Chi-square test, $p > 0.05$; Table 4). Likewise, the daily income, education level, age, groundwater drinking period and residency in village are not significantly different among those having UAs $\leq$ 100 μg L^{-1} and those who had UAs > 100 μg L^{-1} (Mann–Whitney's *U* test, $p > 0.05$; Table 5). Nevertheless, adult was likely to have UAs > 100 μg L^{-1} than children (Chi-square test, $p < 0.05$; Table 4). Mean rank of water drunk per day of a group having UAs > 100 μg L^{-1} (136) is higher than those having UAs $\leq$ 100 μg L^{-1} (112). This suggested that those having UAs > 100 μg L^{-1} significantly drank higher amount of water than those having UAs $\leq$ 100 μg L^{-1} (Mann–Whitney's *U* test, $p < 0.05$).

Table 4 Characteristics of two groups of study participants separated by arsenic concentration in urine

Variables	*n*	UAs $\leq$ 100 μg L^{-1}	UAs > 100 μg L^{-1}	χ^2	*p*
Gender				2.95	0.086
Female	163	128	35		
Male	72	49	23		
Age groups				7.56	0.006
Aged $\leq$12 years	21	21	0		
Aged >12 years	214	156	58		
Location of the tube well				0.24	0.627
Share with others	124	95	29		
Well at home	111	82	29		
Other use of groundwater				0.21	0.65
No	91	70	21		
Yes	144	107	37		
Arsenicosis sign				0.04	0.842
No	108	82	26		
Yes	127	95	32		
Smoking status				4.86	0.088
No	155	123	32		
Yes, currently	74	49	25		
Yes, previously	6	5	1		

UAs arsenic concentration in urine

Table 5 Comparison of daily income, education level, age, groundwater drinking period, residency period and amount of water drunk per day between two groups of arsenic concentration in urine

Variables	*N*	Median	*Z*	*p*
Daily income (USD)[a]			−0.24	0.813
UAs ≤ 100 μg L^{-1}	177	1.00		
UAs > 100 μg L^{-1}	58	1.00		
Education levels (y)[b]			−1.50	0.134
UAs ≤ 100 μg L^{-1}	177	2.00		
UAs > 100 μg L^{-1}	58	1.00		
Age (y)			−1.84	0.065
UAs ≤ 100 μg L^{-1}	177	39.0		
UAs > 100 μg L^{-1}	58	44.0		
Groundwater drinking period (y)			−1.26	0.208
UAs ≤ 100 μg L^{-1}	177	18.0		
UAs > 100 μg L^{-1}	58	18.0		
Residency in village (y)			−1.30	0.193
UAs ≤ 100 μg L^{-1}	177	32.0		
UAs > 100 μg L^{-1}	58	38.0		
Water drunk per day (L/d)			−2.49	0.013
UAs ≤ 100 μg L^{-1}	177	2.00		
UAs > 100 μg L^{-1}	58	2.00		

[a] Daily income was, respectively, coded 1, 2, 3 and 4 as earned 8000 riels or less, earned 20,000 riels or less, earned 40,000 riels or less and earned more than 40,000 riels groups

[b] Education levels, which were grouped as none, primary school or less, secondary school or less, high school or less and beyond high school, were coded 1, 2, 3, 4 and 5, respectively

Conclusions

Field survey indicated that among all respondents, 42.3 % were illiterate and 84.6 % could earn less than 8.00×10^3 KHR (USD 2.00) per day. Females and adults were more likely to be diagnosed for arsenicosis symptoms than males and children. Although arsenicosis patients and their asymptomatic villagers were not significantly different in making the daily income, their age, education levels, residencies in the village, groundwater drinking period and amount of water drunk per day were significantly different. Arsenicosis patients were significantly older and less educated than their asymptomatic villagers; they lived longer in the village and drank groundwater longer and higher amount of water than their asymptomatic villagers. A survey showed that the discrimination and behavior toward arsenicosis patients were negligible. We believe that the positive development was due to various educational programs and application of information, education and communication (IEC) of the relevant NGOs and local authorities in the affected areas of the rural Cambodia. However, most of arsenicosis patients have called for the assistance and support in healthcare services and medication to improve their health and the follow-up for severe patients. In fact, Cambodian people can access to public healthcare service in their commune health center. However, the healthcare service is very limited. Health officials and/or relevant authorities should improve healthcare system in the arsenic-affected areas of the rural Cambodia to heed the health of the exposed populations and arsenicosis patients. This study suggests that residents in Kandal study area are currently at risk of arsenic although mitigating actions have been implemented. Therefore, more commitment should be made to address this pressing public health issue in rural Cambodia.

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