OP-3

Arsenic health risk in foodstuffs in the Mekong River basin of Cambodia

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Abstract

In the present study, we examine the magnitude of arsenic contamination in foodstuffs in the Mekong River basin of Cambodia. Foodstuff, soil and biological samples were collected from Kratie, Kampong Cham, Prey Veng and Kandal provinces and analysed for exposure levels. Moreover, daily intake of inorganic As was calculated to examine the health risk. Analytical results revealed that the means of total As in paddy soils and paddy rice in Kandal were significantly higher than those in Kampong Cham province. Concurrently, significantly positive correlation between the total As in paddy soils and paddy rice was found. Calculation indicated that the upper end of the range of the daily dose of inorganic arsenic of the residents in Kandal was greater than the tolerable daily intake. 26.1 % of the participants (n = 23) had As concentrations in their fingernails greater than 1.00 μg g^{-1}, indicating As toxicity. These results suggest that rice arsenic can be an additional source which is attributable to the high arsenic accumulation in human bodies in the Mekong River basin of Cambodia. Mitigation actions should take arsenic in agricultural produces into account to ensure protection and prevention of the potential adverse health effects of Cambodian people.

Keywords: Arsenic; groundwater; rice; foods; Cambodia

1. INTRODUCTION

Arsenic is a ubiquitous contaminant; drinking arsenic-rich groundwater becomes a major public health concern in Cambodia and elsewhere. The elevated concentrations of arsenic in drinking water in Cambodia were firstly reported by [1]. Subsequently, numerous studies had been documented the dangerous concentrations of arsenic in shallow groundwater [2]. Concurrently, physical, chemical and biological processes controlling the arsenic release to groundwater have been also studied [3]. Consequently, Sampson et al. [4] released the first outbreak of arsenicosis in the Kandal provinces. It was believed that rice grown in the arsenic-contaminated soils had greater arsenic concentration in the grain than that grown the arsenic-free soils. In the present study, we examine the adverse health effects of arsenic contamination in the Mekong River basin of Cambodia. The main objectives of the present study were to (1) determine a distribution of total arsenic concentrations in the main daily foodstuffs of populations residing in the Mekong River basin of Cambodia and (2) compare the regional difference in total arsenic concentrations in rice, fish and vegetable among the proposed study areas.

2. MATERIALS AND METHODS

2.1 Field sampling

Three staple daily foodstuffs namely rice (uncooked and

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cooked), fish (snakehead and catfish) and fruit vegetable (cucumber, gourd, papaya, pumpkin and tomato) were collected from three provinces in the Mekong River basin of Cambodia (Fig. 1).

2.2 Sample analysis

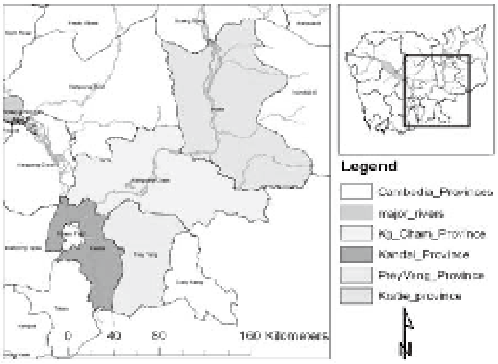

Fig. 1 Map of study area

Acid-digestion was performed for all samples. Briefly, approximately 0.10 g of rice or fish was weighed into 15 ml polyethylene tube. 1.00 ml of concentrated HNO_3 (65%) was added into each tube. The tube was then capped and left in a hood at room temperature. After 48 h, 9.00 ml of deionized water was added and filtered (0.45μm) into a fresh tube. Similarly, 0.10 g of vegetable was weighed into 15 ml polyethylene tube, 2.00 ml of HNO_3 (65%) was added into each tube and allowed to stand 24 h in hood at room temperature, after which 2.00 ml of H_2O_2 (30%) was successively added, followed by heating at 100 oC for 30 min. Heating was continued until the digestate became clear and made up to 10 ml volume. Finally, digestate was filtered (0.45 μm) into a fresh tube. All filtrates were stored in a fridge at 4 oC until chemical analysis. Concurrently, standard reference materials (SRMs) were treated in the same manner of samples to check the accuracy and precision of digestion methods. All chemical measurements were employed by an inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7500 ce).

3. RESULTS AND DISCUSSION

A significantly positive correlation ($r (14) = 0.826$, $p < 0.01$) between $[As]_{tot}$ in paddy soils and paddy rice was observed (Fig. 2).

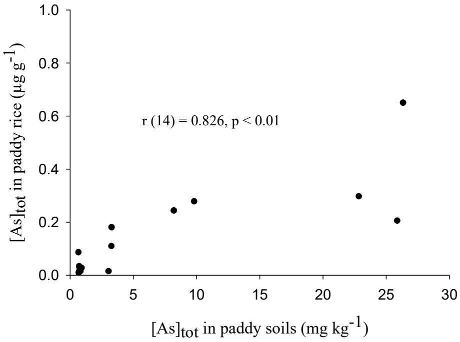

Fig. 2 A correlation between total arsenic concentrations in paddy soils and rice grains in the Mekong River basin of Cambodia.

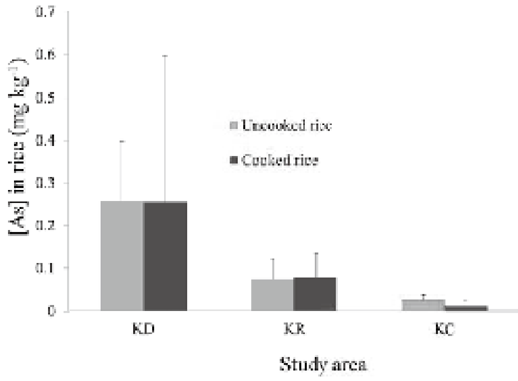

Fig. 3 Distribution of arsenic concentrations in rice in each of the study areas

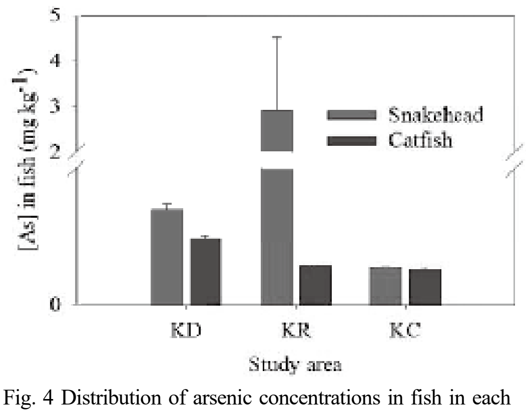

Fig. 4 Distribution of arsenic concentrations in fish in each of the study areas

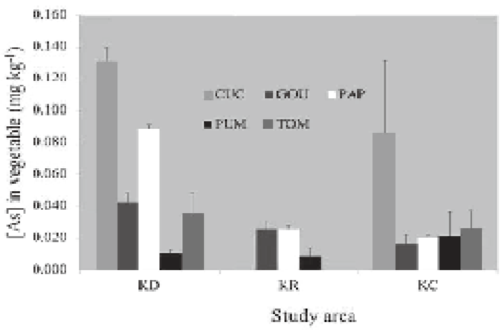

Fig. 5 Distribution of arsenic concentrations in vegetables in each of the study areas

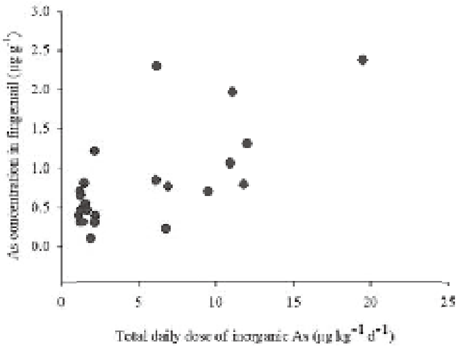

Fig. 6 Correlation between total daily intake and As concentration in fingernail

Table 1 A comparison of the total arsenic concentrations (mg kg^{-1}) in paddy soil and paddy rice (μg g^{-1}) in Kandal (n = 8) and Kampong Cham (n = 8)

Variables	Mean ± SD	Median	Range	*t*	*df*	*p*
Paddy soil				3.271	7.001	0.014
Kandal	12.858 ± 10.430	9.040	3.070 - 26.360			
Kampong Cham	0.794 ± 0.088	0.780	0.680 - 0.930			
Paddy rice				3.261	7.229	0.013
Kandal	0.247 ± 0.187	0.224	0.014 - 0.649			
Kampong Cham	0.029 ± 0.024	0.025	0.008 - 0.085			

The *t* and *df* were adjusted because variances were not equal, SD: Standard deviation

Table 2 Summary of $[As]_{tot}$ (μg g^{-1}), $[As]_i$ (μg g^{-1}), daily intake (μg d^{-1}) and daily dose (μg kg^{-1} d^{-1})of inorganic arsenic concentration in each of the study area

	Kandal		Kratie		Kampong Cham	
Foodstuffs	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice						
$[As]_i$	0.204 ± 0.274	0.008 - 0.951	0.064 ± 0.046	0.004 - 0.152	0.010 ± 0.009	0.003 - 0.025
Daily intake	91.784 ± 123.436	3.546 - 428.108	28.590 ± 20.691	1.917 - 68.360	4.484 ± 3.840	1.478 - 11.124
Daily dose	1.765 ± 2.374	0.068 - 8.233	0.550 ± 0.398	0.037 - 1.315	0.086 ± 0.074	0.028 - 0.214
Fish						
$[As]_i$	0.018 ± 0.003	0.014 - 0.022	0.150 ± 0.184	0.008 - 0.399	0.008 ± 0.000	0.007 - 0.008
Daily intake	0.765 ± 0.144	0.618 - 0.951	6.435 ± 7.872	0.358 - 17.115	0.341 ± 0.018	0.305 - 0.358
Daily dose	0.015 ± 0.003	0.012 - 0.018	0.124 ± 0.151	0.007 - 0.329	0.007 ± 0.000	0.006 - 0.007
Vegetable						

$[As]_i$	0.043 ± 0.033	0.007 - 0.098	0.014 ± 0.008	0.003 - 0.029	0.024 ± 0.023	0.006 - 0.096
Daily intake	3.080 ± 2.391	0.480 - 7.030	0.995 ± 0.580	0.190 - 2.085	1.688 ± 1.638	0.450 - 6.865
Daily dose	0.059 ± 0.046	0.009 - 0.135	0.019 ± 0.011	0.004 - 0.040	0.032 ± 0.031	0.009 - 0.132
All (Foods)						
Daily intake	95.629 ± 125.971	4.644 - 436.089	36.021 ± 29.143	2.465 - 87.560	6.513 ± 5.496	2.233 - 18.347
Daily dose	1.839 ± 2.423	0.089 - 8.386	0.693 ± 0.560	0.047 - 1.684	0.125 ± 0.106	0.043 - 0.353

Inorganic arsenic was assumed to be 10% in fish, 80% in rice and 70% in vegetable. The daily consumption rates of fish, rice and fruit vegetable were 42.86 (g d^{-1}), 450 g d^{-1} and 71.43 g d^{-1} respectively. The average body weight of Cambodia residents was 52 (kg)

Statistical analyses indicated that there were significant differences in arsenic concentrations in uncooked and cooked rice among the three study areas (Kruskal-Wallis test, $p < 0.05$) (Fig. 3). However, pairwise comparisons revealed that there was no significant difference in arsenic concentrations in uncooked and cooked rice in Kandal (Wilcoxon Signed Rank test, $p = 0.203 > 0.05$) and Kratie (Wilcoxon Signed Rank test, $p = 0.386 > 0.05$) provinces. It was interesting that arsenic concentrations in uncooked rice were significantly higher than those in cooked rice in Kampong Cham province (Wilcoxon Signed Rank test, $p = 0.005 < 0.01$). These findings suggested that some households in Kandal and Kraites are still using groundwater for cooking where nobody used Kampong Cham province. In addition, washing rice prior to cooking may reduce the arsenic concentrations in cooked rice. There were significant regional differences in the means of $[As]_{tot}$ in fish among Kandal (0.178 ± 0.034 µg g^{-1}), Kratie (1.502 ± 1.837 µg g^{-1}) and Kampong Cham (0.080 ± 0.004 µg g-1) (One-Way ANOVA test) (Fig. 4). Likewise, significant regional differences in the means of $[As]_{tot}$ in vegetables among Kandal (0.062 ± 0.048 µg g^{-1}), Kratie (0.020 ± 0.012 µg g-1) Kampong Cham (0.043 ± 0.033 µg g^{-1}) were observed (One-Way ANOVA test) (Fig. 5). Moreover, positive significant correlations between total daily dose of As with As concentration in fingernail were found (Fig. 6).

4. CONCLUSIONS

Analytical results revealed that there was no significant differences in arsenic concentrations in uncooked and cooked rice in Kandal and Kratie provinces although significant regional difference in arsenic concentrations in uncooked and cooked rice among the three study areas were observed. Similarly, arsenic concentrations in fish and vegetables were relatively high in Kandal. It is apparent that foodstuffs in Kandal province were highly contaminated comparing to those in Kratie and Kampong Cham provinces, except for snakehead fish, in which arsenic concentration was found highest in Kratie province. Calculation of daily inorganic As intake indicated that the daily dose of inorganic As was greater than the lower limits on the benchmark dose for a 0.5% increased incidence of lung cancer ($BMDL_{0.5}$ equals to 3.0 µg d^{-1} kg^{-1}body wt.). Analysis of fingernail samples indicated that 26.1 % of the participants were confronted with As toxicity. These findings suggested that the Kandal residents are at high risk of arsenic intake comparing to those who are living in Kratie and Kampong Cham provinces. As in rice is an additional source which is attributable to high As accumulation in human bodies in the Mekong River basin of Cambodia.

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REFERENCES

[1] Japanese International Cooperation Agency (JICA). 1999. The Study of Groundwater Development in Southern Cambodia. Unpublished Draft Report by Kokusai Kogyo Co Ltd to Ministry of Rural Development, Phnom Penh, Cambodia.

[2] Buschmann J, Berg M, Stengel C, Sampson ML. 2007. Arsenic and manganese contamination of drinking water resources in Cambodia: coincidence of risk areas with low relief topography. Environ Sci Technol 41(7):2146-2152.

[3] Polizzotto ML, Kocar BD, Benner SG, Sampson M, Fendorf S. 2008. Near-surface wetland sediments as a source of arsenic release to ground water in Asia. Nature 454(7203):505-508.

[4] Sampson ML, Bostick B, Chiew H, Hangan JM, Shantz A. 2008. Arsenicosis in Cambodia: Case studies and policy response. Appl Geochem. 23, 2976-2985.