Title	HUMAN HEALTH RISK ASSESSMENT THROUGH FOOD CHAIN IN SOME AREAS WITH HIGH ARSENIC CONCENTRATION
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Citation	Annual Report of FY 2004, The Core University Program between Japan Society for the Promotion of Science (JSPS) and Vietnamese Academy of Science and Technology (VAST). 2005, p. 41-46
Version Type	VoR
URL	https://hdl.handle.net/11094/13040
rights	
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HUMAN HEALTH RISK ASSESSMENT THROUGH FOOD CHAIN IN SOME AREAS WITH HIGH ARSENIC CONCENTRATION

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ABSTRACT

Summary. Human health risk assessment through food chain in some areas with high arsenic concentration in groundwater in Ha Nam and Thai Nguyen provinces were carried out .The resulting shows that the health risk in Ha Nam province mainly caused by arsenic contamination in drinking water. Maximum hazard index in Ha Nam is about HI=134, in Thai Nguyen is about HI=13.2.I The incremental lifetime cancer risk (ILCR) for resident child is $4.3.10^{-3}$ $(mg/kg\text{-}day)^2$, for resident adult is $6.2\ 10^{-3}$ $(mg/kg\text{-}day)^2$. It is unclear to conclude about the risk through food chain (vegetable, fish).Findings also showed that health risk in Ha Nam province is significant greater than that in Thai Nguyen province. The risk assessed in Ha Nam province is serious high and at unacceptable level. The risk for adults is 1.5 times greater than that for children. In Dai Tu, Thai Nguyen where natural minerals exploited, the risk has not clearly found. In addition, there is no difference in the diseased arsenic risk for adults and children.

INTRODUCTION

Human health risk assessment through food chain in some areas with high arsenic concentration is an alarming issue, currently is serious concerns in Viet Nam. The major contamination source is high contaminated arsenic in groundwater that is used for drinking. Other health risk sources are pollutants in soil, air environments which intake into human body through ingestion, respiration and dermal exposure. One of the direct and high risks is through food chain includes drinking water and daily food. In this study some major factors concerning with health risk assessment were researched: 1- Analysis the arsenic concentration contaminated in groundwater, vegetable and food (fish); 2- recipient targets; and 3- Assessment of arsenic daily intake dose through drinking water, vegetable and fish.

Based on calculated risk index caused by arsenic contamination in groundwater and food (vegetable and fish), health risk assessment was identified and found at higher level in Ha Nam province compared to Thai Nguyen province.

METHODOLOGY AND EXPERIMENTAL RESEARCH

Human health risk assessment was carried out by following steps: Hazard identification, Dose-Response evaluation, Exposure assessment, Risk characterization and Uncertainty analysis.

Equipment and chemicals

- Atomic absorption Spectrometer Hidrid Vapor Generator (HVG), Shimadzu 6800-Japan.
- Chemicals: KI 10%, $NaBH_4$, HCl; H_2SO_4, H_2O_2.

RESULTS AND DISCUSSION

Hazard identification.

Arsenic is a naturally occurring element widely distributed in the earth crust. In the environment, arsenic combines with oxygen, chlorine, and sulfur to form inorganic compounds; and with carbon and hydrogen to form organic arsenic compounds III and V valence. Many inorganic arsenic compounds can dissolve in water and absorb through the gastrointestinal tract and lungs, distributed primarily to the liver, kidney, lung, spleen, aorta, and skin…; and excreted mainly in the urine at high rate up to 80%. Arsenic is human chemical carcinogens (classified: A) [1,2,7,8,9] .the carcinogenic effects of arsenic may increase the risk of lung, skin, bladder, liver, kidney and prostate cancers.

Arsenic contamination in groundwater in Viet Nam and some areas in the world is anxious for peoples. About 150 000 Bangladesh people had got arsenouses disease. The geology of the Red river delta in Vietnam found similar to the geology of Ganges river in Bangladesh, therefore it is explainable the fact that the arsenic contamination in groundwater in some provinces including Ha Noi, Ha Tay, Nam Dinh, Ha Nam, etc. However, in some mineral mining areas far way from Red river deltas like Dai Tu district, Thai Nguyen province, also found having high arsenic concentration in groundwater.

The report studied on the human health risk assessment of arsenic through daily food-chain based on the arsenic concentration in the groundwater, in vegetables (e.g mustard greens, salad green, cabbage, carrot, and spinach), and in the fish (e.g carp, hypophthalmichthys and tilapia). Table 1 shows the average arsenic concentrations in groundwater in five communes of Ha Nam province and in mineral mining area in Dai Tu, Thai Nguyen province.

Table 1. Average Arsenic concentrations in groundwater, vegetable and fish in some areas in Ha Nam and Thai Nguyen provinces ***(March-April, 2004)***

	As [ppb] Communes	0-10	11-25	26-50	51-100	101-250	251-500	> 500
Arsenic distribution in Ha Nam Province	Ng.Lu-HN	18	20	25	31	22	7	1
	B.Nghia-HN	22	2	6	11	48	33	2
	Nh. Chinh HN	12	11	10	10	22	3	1
	Van Ly-HN	0	1	7	42	0	0	0
	Le Ho-HN	7	3	6	6	11	2	0
	Total-HN	59	37	54	100	103	45	4
	Ratio [%]	14.67	9.20	13.43	24.87	25.62	18.09	0.99

	Ha Nam [As]			**Thai Nguyen, Dai Tu** [As]		
	G.Water [mg/l]	Vegetable [mg/kg]	Fish [mg/kg]	G.Water [mg/l]	Vegetable [mg/kg]	Fish [mg/kg]
Min.	0.007	0.76	0.146	0.001	0.57	0.103
Average	0.100	1.321	0.549	0.032	1.135	0.472
Max.	0.500	14.58	1.737	0.134	12.51	1.150

Arsenic concentration in groundwater (C_{water}) was been analyzed for 402 tube wells in Ha Nam and 15 wells in DaiTu, Thai Nguyen,. Arsenic contamination was classified into 7 concentration levels as 0-10, 10-25, 26-50, 51-100, 101-250, 251-500 and > 500ppb). The average value of arsenic concentration found in vegetables and fishes that showed in the table 1 is calculated as average concentration of all tested samples, respectively. This is based on the assumption that these foods are daily accepted (see table 1)

Dose-Response evaluation

The acute lethal dose to humans has been estimated to be about 0.6mg/kg-day[2,3,4,5,6]. Toxicity data is available for threshold and non-threshold effects from arsenic. Oral toxicity reference values for arsenic are: RfD of 3.0E-04mg/kg-day and oral Slope Factor (SF) of 1.5(mg/kg-day)-1[2,3,4,5,6].

Table 2. Average Daily Dose for ingestion of water for resident child.

No	C_{water} x10^{-3} mg/L	IR_{water} L/day	EF day/year	ED year	AT day	BW kg	ADD_{drink} mg/kg-day	HQ= ADD/RfD	ILCR= ADDxSF
1	10	1.5	280	5	1825	20	0.00057	1.90000	$8.5x10^{-5}$
2	50	1.5	280	5	1825	20	0.00287	9.56666	$4.3x10^{-4}$
3	100	1.5	280	5	1825	20	0.00575	19.66666	$8.6x10^{-4}$
4	150	1.5	280	5	1825	20	0.00863	28.76666	$1.3x10^{-3}$
5	250	1.5	280	5	1825	20	0.01438	47.93333	$2.1x10^{-3}$
6	500	1.5	280	5	1825	20	0.02876	95.86666	$4.3x10^{-3}$

Table 3. Average Daily Dose for ingestion of water for resident adult

No	water x10^{-3} mg/L	IR_{water} L/day	EF day/year	ED year	AT day	BW kg	ADD_{drink} mg/kg-day	HQ= ADD/RfD	ILCR= ADDxSF
1	10	5.0	330	25	125	55	0.00082	2.73333	$1.2x10^{-4}$
2	50	5.0	330	25	125	55	0.00411	13.70000	$6.1x10^{-4}$
3	100	5.0	330	25	9125	55	0.00821	27.36666	$1.2x10^{-3}$
4	150	5.0	330	25	9125	55	0.01233	41.10000	$1.8x10^{-3}$
5	250	5.0	330	25	9125	55	0.02054	68.46666	$3.1x10^{-3}$
6	500	5.0	330	25	9125	55	0.04109	136.9666	$6.2x10^{-3}$

Similarly, Average Daily Dose for ingestion of vegetable and fish for resident child and resident adult in Ha Nam and Thai Nguyen provinces were calculated and showed in table 4

Table 4. Average Daily Dose for ingestion of water, vegetable, and fish for resident child and adult in Ha Nam and Thai Nguyen

No	C_{water} mg/kg	IR_{water} g/kgBw/day	EF day/year	ED year	AT day	BW kg	ADD x10^{-3} (mg/kg-day)	HQ= ADD/RfD	ILCR= ADDxSF
Resident child (5 year old, 20 kg)									
G.Water-TN	32.10^{-3} mg/l	1.5L	280	5	1825	20	0.001841	6.1366	$2.7x10^{-4}$
Veg.-TN	2.169	11g	280	5	1825	20	0.000915	3.0500	$1.3x10^{-4}$
Fish -TN	0.572	2.5 g	150	5	1825	20	0.000030	0.1000	$4.5x10^{-6}$
Veg.-HN	2.981	11g	280	5	1825	20	0.001257	4.1900	$1.8x10^{-4}$
Fish-HN	0.649	2.5 g	150	5	1825	20	0.000034	0.1133	$5.1x10^{-6}$
Resident adult (50 years old, 55kg)									
G.Water-TN	32.10^{-3} mg/l	5L	330	25	9125	55	0.002630	8.7666	$3.9 x10^{-4}$
Veg-TN	2.169	195g	330	25	9125	55	0.006952	23.1733	$1.0x10^{-3}$
Fish -TN	0.572	5.0	330	25	9125	55	0.000047	0.15666	$7.1x10^{-5}$
Veg.- HN	2.981	195g	330	25	9125	55	0.009555	31.8500	$1.4x10^{-3}$
fish - HN	0.649	5.0	330	25	9125	55	0.000053	0.17666	$7.9x10^{-6}$

In this report these values were applied for risk assessment. Average Daily Dose for each exposure pathway was calculated using standard equation for risk assessments [x] [Chulabhorn,],

$$ADD_{ig} = \{[\ C_{water}\ x\ IR_{water} + C_{veg.}\ x\ IR_{veg} + C_{meat}\ xIR_{meat}]\ x\ EF\ x\ ED\}\ /\ [AT\ x\ BW\ ] \qquad [1]$$

where

ADD: average daily dose from ingestation (mg/kg-day)

C_x: Arsenic concentration in water, in vegetable, in fish (mg/l or mg/kg)

IR_x: Water, vegetable or fish ingestation rate (L/day, gfood/kgbw/day); assumed values

EF: exposure frequency(days/year) [3,4,5,6]; assumed values

ED: exposure duration (years) ; assumed value [3,4,5,6]

AT : averaging time (days)- threshold chemical (calculated value)
BW : body weight (kg), Assumed value
According biological factory of Vietnamese peoples, human receptor exposure as child resident in 5 year old, their weight is 20kg[3,4,5,6] .The Adult resident in 50 year old, with 25 years exposure and their weigh is 55kg[3,4,5,6]. Average Daily Dose (ADD) was calculated with highest concentrations in every level for resident child and for the resident adult as showed in table 2 and 3. respectively..

Exposure assessment, Risk characterization and Uncertainty analysis

Human health risk is determined by calculating a hazard quotient for contaminant with threshold effects. A hazard quotient (HQ) is equal to the ratio of the estimated average daily dose rate (ADD) and reference dose value (R_fD):

$$HQ = ADD/ RfD \qquad (2)$$

When hazard quotient value is greater than 1, it indicates an unacceptable exposure scenario; and less than or equal to 1 it indicates an acceptable exposure scenario.
Total risk from threshold chemicals can be estimated by adding the hazard quotient for individual pathways to obtain a hazard index(HI):

$$HI= HQ_{Water} + HQ_{Veg.} + HQ_{Demal} + HQ_{x} +... \qquad (3)$$

Table 5. Hazard Index for resident child and adult

	Ha Nam						Thai Nguyen
As in G,Water	10 ppb	25 ppb	50 ppb	100 ppb	250 ppb	500 ppb	32ppb
Resident child							
HQ water (ADD/RfD)	*2.5570*	*12.7858*	*25.5666*	*38.3333*	*63.9000*	*127.8533*	8.7671
HQ veg. (5 kinds))	*5.9666*						4.3333
HQ fish (3 kindsi)	0.1500						0.1333
Hazard Index HI= Total HQ	*8.6736*	*18.9024*	*31.6832*	*44.4499*	*70.0166*	*133.9699*	*13.2337*
Rating risk	*low*	*low*	*intermedia te*	*intermedia te*	*intermedia te*	*high*	*low*
Resident adult							
HQn-ic (ADD/RfD)	2.2831	11.4155	22.8310	34.2465	61.6438	114.1552	7.3059
HQ Rau (5 lo'i)	*5.9666*						4.3333
HQ c. (3 lo'i)	0.1500						0.1333
HI= Total HQ	8.3997	17.5321	28.9476	40.3631	67.7604	120.2718	11.7725
Rating risk	*low*	*low*	*intermedia te*	*intermedia te*	*intermedia te*	*high*	*low*

For the purposes of qualitatively describing levels of unacceptable hazard indices as following ratings:

Rating	HI range
Low risk	>1 to <10
Intermediate risk	>10 to <100
High risk	>100

Table 5 shows the initial results of total risk (HI) concerning with drinking water, vegetable, and fish. As we can see in the table 5, hazard quotient value of arsenic contamination at the level >10ppb is greater than 1 (HQ>1) which is unacceptable. According to Hazard Index of Arsenic (HI) with arsenic contamination at the level of 100-250ppb and > 250ppb, risk values will be in the range of 24-70 (Intermediate risk) and > 100 (High risk), respectively.
The incremental lifetime cancer risk (ILCR)[2,3,5,6,7,8,9] calculated for tests in Ha Nam and Thai Nguyen were showed in table 6, where cancer risk in Ha Nam province for child is 4 in 1000 and for adult is 6 in 1000. Cancer risk in Thai Nguyen province for child and adult is 4 in 10000, respectively.

Table 6. Total incremental lifetime cancer risk ILCR

Sources polluted	ILCR -Ha Nam		ILCR-Thai Nguyen	
	Res. Child	Res.Adult	Res.Child	Res.Adult
Water	$4.3x10^{-3}$	$6.2x10^{-3}$	$2.7x10^{-4}$	$3.9\ x10^{-4}$
Vegetable	$1.8x10^{-4}$	$1.8x10^{-4}$	$1.3x10^{-4}$	$1.8x10^{-4}$
Food (fish)	$5.1x10^{-6}$	$7.9x10^{-6}$	$4.5x10^{-6}$	$7.1x10^{-6}$
Total ILCR	$4.48x10^{-3}$	$6.38\ x10^{-3}$	$4.0x10^{-4}$	$4.3x10^{-4}$

Uncertainty analyses. It is clear that health risk assessment is valuable tool for environmental toxicology, however there are a number of uncertainties involved such as lack of adequate data in term of representative species and quatity; assumptions sometime are inappropriate to Vietnamese people, risk analysis often calculated as the highest level that is not suitable to practice, etc.

CONCLUSION

1- In this study, it is first time health risk assessment caused by arsenic contamination was carried out in Ha Nam and Thai Nguyen provinces.
2- The resulting from analysis data, health risk in Ha Nam province mainly caused by arsenic contamination in drinking water with high level (85% tested samples are exceeded Vietnamese standard; around 70% surveyed tube wells having arsenic content from 50ppb to 250ppb). It is unclear to conclude about the risk through food chain (vegetable, fish).
3- Findings also showed that health risk in Ha Nam province is significant greater than that in Thai Nguyen province. The risk assessed in Ha Nam province is serious high and at unacceptable level. The risk for adults is 1.5 time greater than that for children. In Dai Tu, Thai Nguyen where natural minerals exploited, the risk has not clearly found. In addition, there is no difference in the diseased risk for adults and children.
4- This study just very briefly investigated on health risk assessment caused by arsenic contamination through food chain. In further studies, some other issues should be taken into account such as components of food chain, environmental factors that relating to human health, etc.

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