Health Consultation

Exposure Investigation Report

KEA'AU 8.5 AND 9.5 MILE CAMPS

KEA'AU, HAWAII COUNTY, HAWAII

EPA FACILITY ID: HIN000908281

AUGUST 15, 2008

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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Prepared by:

U. S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
And
Hawaii Department of Health

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Abbreviations and Acronyms

A3	Arsenous acid
A5	Arsenic acid
ATSDR	Agency for Toxic Substances and Disease Registry
ACGIH	American Conference of Governmental Industrial Hygienists
BEI	Biological Exposure Index
CDC	Centers for Disease Control and Prevention
DMA	Dimethylarsinic acid
EI	Exposure investigation
FDA	Food and Drug Administration
HDOH	Hawaii Department of Health
MMA	Monomethylarsonic acid
NCEH	National Center for Environmental Health (CDC)
ppm	parts per million
µg/L	micrograms per liter
USFDA	United States Food and Drug Administration

Executive Summary

Background

Two residential areas, 8.5 Mile and 9.5 Mile Camps, have existed for many decades. These Camps are located in Kea'au Hawaii which is about 9 miles south of Hilo, Hawaii on the Big Island. These Camps are adjacent to former sugar plantations. Residents have cultivated community gardens on the camp grounds and consume produce from these gardens.

The Hawaii Department of Health tested soil from the community gardens and found arsenic with an average soil concentration of 331 mg/kg. The Hawaiian Islands have relatively high levels of naturally-occurring arsenic in the volcanic soils (5-20 mg/kg). The higher levels of soil arsenic found in the garden are most likely from past use of sodium arsenite and other soil amendments used in sugar production. Garden produce was also tested for arsenic and levels were similar to produce found in grocery stores.

Purpose of Investigation

Despite arsenic testing efforts in the soil and produce, information about arsenic exposure from living near contaminated soil, gardening in the soil, playing in the soil, and bringing residual soil/dirt into the home from normal household activities was not available. The purpose of this exposure investigation was to identify if current residents have unusual exposure to arsenic by measuring arsenic in their urine.

Tested Population

Thirty-three residents from the Camps were tested for urine arsenic over a three month period in the fall of 2005. The average age of the participants was 48. Six participants were children between the ages of 10 -18. There were 18 males and 15 females. Seven participants were retested because they exceeded screening levels for inorganic arsenic in three consecutive samples and food sources may have contributed to their urine arsenic levels.

Conclusions

1. This investigation could not determine if living, gardening, or playing near arsenic contaminated soil and bringing residual soil/dirt into the home from normal household activities contributed to urine arsenic levels among participants. The arsenic concentrations in participants may primarily reflect dietary contributions from seafood, seaweed, rice and other food sources. In general, arsenic from such food sources is not considered harmful.

2. The majority of adults and all children tested for urine arsenic had arsenic levels that are similar to those detected in other populations who eat regular and frequent amounts of seafood. No adverse health effects from arsenic toxicity have been reported in populations who consume regular and frequent quantities of seafood.

3. Seven adults were retested because food sources may have contributed to their test results. All retested participants had urine arsenic levels that declined and had levels that are similar to populations that eat regular and frequent amounts of seafood. No adverse health effects from arsenic toxicity have been reported in populations who consume regular and frequent quantities of seafood.

Recommendations

1. Although this investigation could not determine if living in an area with arsenic contaminated soil contributed to urine arsenic levels among participants, arsenic soil levels in the community gardens are still considered elevated. Because of continued use of the community gardens, prudent public health measures should be considered including limiting preschool children's access to the community garden.

2. ATSDR/HDOH recommends following general food safety guidelines. Additional general food safety guidelines are outlined below for home-grown fruit and vegetable consumption to reduce potential exposure to metals:

- Wash hands with soap and water after working in the garden and before eating produce from the local garden.
- Wash all fruits and vegetables to remove soil before eating.
- Peel fruits and vegetables to reduce surface contamination.
- Peel root crops (potatoes, carrots, beets, etc.).
- Discard older or outer leaves of leafy vegetables during food preparation.
- Do not compost unused plant parts, peelings, and parings for later use in a fruit and vegetable garden.

3. ATSDR/HDOH recommends the following prudent, protective land use practices to decrease future exposure to arsenic from gardening:

- Avoid putting fingers or tools in mouth when working in the community garden.
- Do not use CCA (arsenic containing) treated lumber to build raised beds.
- Avoid tracking garden soil into the home on clothes, shoes or tools.

Background

Two residential areas, 8.5 Mile and 9.5 Mile Camps, have existed for many decades. The Camps are located in Kea'au, Hawaii which is about 9 miles south of Hilo, Hawaii on the Big Island. There are approximately 60 homes located in 8.5 Mile Camp and 40 homes located in 9.5 Mile Camp. These Camps were two of a number of camp housing areas located within several miles of the sugar mill for the Ola`a Sugar Company which operated from 1900 until 1960. It was renamed the Puna Sugar Company in 1960 and operated until 1982. The Camps are populated largely by ethnic Filipinos, who mostly speak Ilocano in addition to English. Residents have developed community gardens for many years on the camp grounds. Many residents consume the fruits and vegetables grown in these gardens. The current community garden at 9.5 Mile Camp is approximately 4 acres and the community garden at 8.5 Mile Camp is approximately 1 acre.

A recent investigation (HDOH 2007) conducted by the Hawaii Department of Health (HDOH) found high levels of total arsenic in soil in a number of locations around the town of Kea`au. Soil from the community gardens was also tested in this effort. The average surface soil concentration in the community gardens was 331 mg/kg (range 304-366 mg/kg). The Hawaiian Islands have relatively high levels of naturally-occurring arsenic in the volcanic soils (5-20 mg/kg). The higher levels of soil arsenic found in the garden are most likely from past use of sodium arsenite, a herbicide used in sugar production between approximately 1915-1950. In the past other unknown soil amendments contaminated with arsenic may have been used in the community gardens.

Arsenic is less toxic when it is tightly bound to soil particles. The use of soil amendments in gardens can affect soil chemistry and influence the bioaccessibility of arsenic in the soil. Bioaccessiblity is a term used to describe how much of a substance is dissolved in gastric fluids and can potentially be absorbed by the body. Bioaccessibility analysis of the soil arsenic in the Kea'au area showed varying levels of bioaccessible soil arsenic. The community gardens had the highest bioaccessible soil arsenic levels at 19%, and other areas had bioaccessible soil arsenic at about 7% (HDOH 2007).

Due to the high levels of arsenic in the community gardens and its bioaccessibility, HDOH advised residents of the potential exposure from arsenic in the garden in April 2005. The residents were advised to keep children out of the gardens and to wash garden vegetables thoroughly before consumption.

To determine if garden produce was safe for consumption, HDOH tested garden produce for arsenic in 2005. Concentrations of total arsenic for garden vegetables fell within or just above the range of arsenic for comparable produce presented in the US Food and Drug Administration *Total Diet Study* (US FDA 2004). These results are reported in the Soil Arsenic Assessment Study (HDOH 2007).

Despite these testing efforts in the soil and produce, information about actual human arsenic exposure from living near contaminated soil, gardening in the soil, playing in the soil, and bringing residual soil/dirt into the home from normal household activities was not available. To better understand human exposure to arsenic among residents in the Camps, the Agency for Toxic Substances and Disease Registry (ATSDR) and HDOH conducted an exposure investigation (EI) to address community concerns and assist in understanding ongoing exposures to arsenic.

The purpose of this exposure investigation (EI) was to identify current residents in the Camps who are most likely exposed to high levels of arsenic from their environment and determine their current level of arsenic exposure. Urine arsenic (total and speciated) levels were measured three separate times over a 3 month period in the same person to assess whether unusual exposure to arsenic is currently occurring among residents in the Camps.

There are three major limitations in this investigation. One, this investigation cannot identify if a particular environmental source (e.g. soil, dust, vegetables etc.) contributed to a person's urine arsenic level. It can only identify if a person's urine arsenic level is unusual and whether dietary sources (i.e. seafood, seaweed, rice and other dietary sources) may have contributed to their level. Two, the results of this investigation are applicable only to the community tested and cannot be generalized to other populations. And three, the results of this exposure investigation cannot be used to predict the future occurrence of disease.

Target Population

The target population for this investigation were current residents at the 8.5 and 9.5 mile Camps. We attempted to recruit 30 residents for the urine arsenic testing. Eligibility criteria were developed to select for the worst-case, nonoccupational exposure scenario. For example, participants who lived closest to the gardens or gardened frequently were preferred, because they may have a significantly higher exposure to arsenic than others. If evidence of increased exposure was not found in this potentially highly exposed group of residents, then those with lower exposure risk factors (e.g. non gardeners) are less likely to be affected.

The eligibility criteria for urine arsenic testing included the following:

- 10 years of age or older
- Currently live in the one of the Camps
- No history of current occupational exposure to arsenic
- Continue to live in the camps while the testing was conducted

Test Procedures

During the week of April 9, 2005, staff from HDOH held a community meeting in both Camps to inform them of the exposure investigation and participation criteria. Community members were asked to sign up if they were interested in participating.

During the week of September 2, 2005, HDOH/ATSDR met with eligible participants in their homes or at the Kea'au Community Center. Many participants were not fluent in English, therefore all informational material (facts sheets, questionnaires, urine collection instructions and consent forms) were translated into Ilocano. Ilocano is the predominant Filipino dialect spoken by participants. An Ilocano interpreter, from HDOH, accompanied the team during urine collection events to ensure appropriate level of understanding and informed consent.

Each adult participant completed a written informed consent form. Parents of children gave written permission to test children. In addition to completing consent forms, each participant was asked a few questions to gather information on risk factors for exposure to arsenic through food pathways, contact with contaminated soil, and use of arsenic containing products.

Urine arsenic samples were collected three separate times from the same individual over a three month period. Serial urine arsenic samples were collected during the weeks of September 2, October 5, and November 8, 2005. A select group of eight individuals were offered retesting a fourth time for urine arsenic because they exceeded the screening level in all three testing events. Dietary sources of arsenic can contribute to inorganic arsenic levels. This select group was offered retesting because dietary sources of arsenic may have interfered with their inorganic arsenic results. This fourth urine collection took place during the week of January 14, 2007.

Urine arsenic is the most reliable method for measuring arsenic exposure, particularly exposures occurring within a few days of the specimen collection. Although a 24-hour urine collection is considered an optimal sample due to fluctuations in excretion rates, most exposure studies have used a first morning void or random sample due to ease of collection (NRC 1999). To control for differences in urine output and dilution, urine creatinine is measured.

A 70 mL plastic urine cup was given to each participant and he/she was instructed to provide a mid-stream void urine sample. Urine samples were random urine samples, not first morning void urine samples. ATSDR/HDOH staff collected the urine sample from the participant, followed proper chain of custody procedures, and froze the urine sample with dry ice for shipment to the National Center for Environmental Health Laboratory (NCEH) in Atlanta, Georgia, for analysis.

Inorganic arsenic is considered to be more toxic than organic arsenic (NRC 1999). Organic arsenic is often found in seafood and shellfish. In some seafood, small amounts of inorganic arsenic can also be present (Buchet 1994 and MacIntosh 1997). Consumption of seafood a few days before urine collection can elevate the total arsenic urine concentration. To minimize interference from the arsenic in seafood, the participants were asked to refrain from eating seafood for three days prior to urine collection. With each round of testing, letters and phone calls were sent to the participants reminding them of the testing date and to avoid seafood consumption a few days prior to urine collection.

Laboratory Method

The NCEH analyzed urine samples for total arsenic using inductively coupled plasma-dynamic reaction cell-mass spectrometry (ICP-DRC-MS). Speciated arsenic was analyzed using high performance liquid chromatography (HPLC). Creatinine concentrations were measured with an automated clinical Kodak 250 analyzer using the manufacturer's single slide, two-point enzymatic method. The laboratory followed method-specific quality assurance and quality control (QA/QC) procedures.

A minimum of 5 ml of urine was required for this analysis. Test results were reported as micrograms of arsenic per liter of urine (µg /L) and as micrograms of arsenic per gram of creatinine (µg/g). The detection limit for total urine arsenic was 0.6 µg/L. Depending on the arsenic species, the speciated arsenic detection limit ranged from 0.3 µg/L to 2 µg/L. Urine creatinine was also analyzed. For a given sample, if the total arsenic concentration was below the level of detection, speciated arsenic was not analyzed.

Comparison Values

Total Urine Arsenic

Arsenic reference ranges are not included in the *Third National Report on Human Exposure to Environmental Chemical (CDC, 2005).* However, the published literature reports urine arsenic concentrations in populations with background exposures. Normal total urine arsenic levels are considered to be less than 50 µg/L in the absence of consumption of seafood or other dietary sources of arsenic (NRC 1999).

Inorganic Urine Arsenic

Currently, there is no national reference range for background concentrations of inorganic arsenic levels in urine samples from the general United States population. However, the results of several studies in the scientific literature indicate that concentrations of inorganic arsenic in people with no unusual exposure to arsenic are usually less than 20 µg/L (Andren 1988, Johnson 1989, Jensen 1991). The American Conference of Governmental Industrial Hygienists (ACGIH) has established a Biological Exposure

Index (BEI) of 35 µg/L for inorganic arsenic to assess the level of contaminants in workers who are exposed in occupational settings. Urine inorganic arsenic levels up to 35 µg/L are considered acceptable in an occupational setting (ACGIH 2001). This BEI occupational level does not indicate a sharp distinction between hazardous and non hazardous exposures. For example, it is possible for an individual's urine concentration to exceed the BEI without incurring an increased health risk. According to the ACGIH, dependence should not be placed on the results of one single specimen because of the variable nature of biological specimens. If a worker consistently exceeds the BEI on different occasions, then the measures should be taken to identify the cause of the exposure and reduce exposure (ACGIH 2001).

For this investigation, a screening level of 20 µg/L for inorganic arsenic was used to evaluate whether additional follow-up was needed. The screening level of 20 µg/L represents an upper background level in unexposed individuals and assumes no large dietary source of arsenic. If a participant exceeded the screening value of 20 µg/L in *all three* testing events, they were offered retesting for urine arsenic because dietary sources of arsenic may have contributed to their inorganic arsenic results.

However, in predominately seafood eating populations, such as in Japan, inorganic urine arsenic has been reported as a mean of 55.27 µg/L with a standard deviation of ± 35.16 µg/L (Yamato 1988). The higher urine arsenic levels in the Japanese are believed to be due to dietary sources such as seafood and seaweed which are common daily foods in the Asian diet. Based on interviews with participants in this investigation, it was determined that dietary habits of the majority of the participants more closely resembled the Japanese or Asian diet than an American diet. The majority of the study participants were Filipino whose dietary habits differ from the typical Western diet. Most of the participants ate rice, vegetables and seafood almost daily. It was difficult to get the participant's compliance to abstain from seafood and seaweed consumption prior to urine collections, a problem the Japanese study also encountered (Yamato 1988).

Because the Filipino participants in this investigation eat much more seafood and seaweed than the typical American diet, it is more appropriate to use the Japanese arsenic comparison values for this investigation. Populations or nations that eat more seafood and seaweed should be compared to the higher urine arsenic levels of the Japanese because the data are essentially confounded by seafood-derived arsenic (Yamauchi 1989).

Results

Urine arsenic is the most reliable method for measuring arsenic exposure (NRC 1999), particularly for exposures occurring within a few days of the specimen collection. Speciated urine arsenic is preferable to total urine arsenic. The speciated forms can distinguish between exposure to inorganic arsenic and its metabolites and the relatively nontoxic forms of organic arsenic, commonly found in seafood and other dietary sources. (Kallman 1990).

All urine samples were above the detection limit. Therefore, all urine arsenic samples were tested for inorganic arsenic, organic arsenic and total arsenic. The inorganic fraction consists of arsenous (III) acid, arsenic (V) acid, and their metabolites, monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA). Organic arsenic species include arsenobetaine, arsenocholine, and tetramethylarsine oxide. Arsenic in seafood is predominantly arsenobetaine and arsenocholine with small amounts of DMA and MMA (NRC 1999).

Organic arsenic is often found in seafood and shellfish. Consumption of seafood a few days before urine arsenic testing can elevate the total arsenic urine concentration. In some types of seafood, small amounts of inorganic arsenic can also be present (Buchet 1994 and MacIntosh 1997) and therefore may elevate inorganic arsenic urine concentrations.

Because urine arsenic measurements reflect only very recent exposure (a few days), it only provides a small window of assessment to arsenic exposure. Periodic urine arsenic measurements in the same individual over a few months provide a more accurate representation of long-term exposure. Consequently, participants in this investigation were tested three times over a three month period to assess arsenic exposure over a longer time period.

Participants

Thirty-three participants completed a consent form and provided a urine sample for arsenic in September, October, and November 2005. Some participants did not participate in all three urine testing events. The population consisted of 27 adults and 6 children, ages 10 to 88 years old. The mean age of the children was 12 years old, and the range was 10 to 18 years old. The 27 adults ranged in age from 19 to 88 years old. The mean age of the adults was 48 years old while the overall median age of the group was 52 years old. There were 18 males and 15 females.

Total Urine Arsenic

Total urine arsenic levels are the sum of organic (dietary arsenic) and inorganic arsenic species. Consequently, total urine arsenic levels can vary greatly in one individual based on dietary habits. Total urine arsenic levels in the participants varied among family members within a single household and also in an individual. The mean and median total arsenic urine concentrations differed slightly among the three testing events. Figure 1 depicts the variation in total urine arsenic levels in each participant in all three months of testing.

Figure 1: Total Urine Arsenic in Participants in November, October, and September 2005

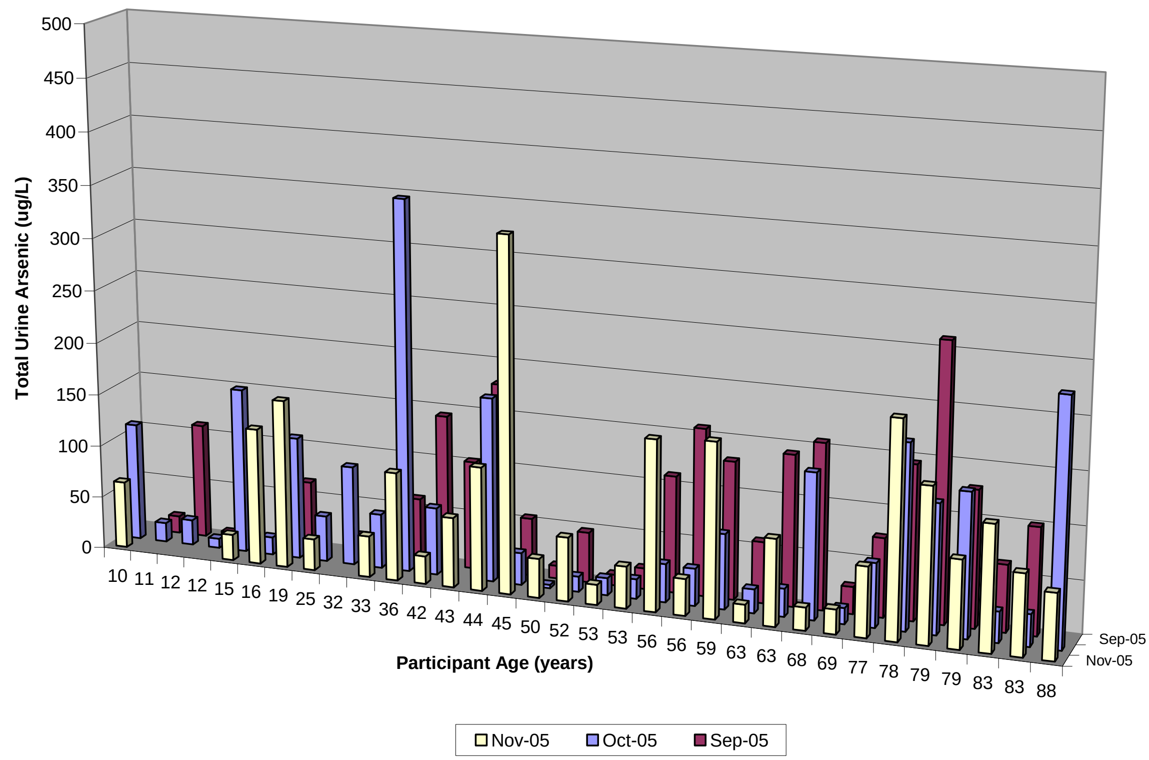


Table 1 summarizes urine arsenic concentrations, total and inorganic arsenic, for all participants in September, October, and November 2005. The mean total urine arsenic levels among participants in all three testing events ranged from 87.67 µg/L to 86.69 µg/L. The highest total arsenic urine level in this investigation was 352.70 µg/L in October 2005.

Table 1. Urine arsenic concentrations in participants in September, October, and November 2005.			
	September 2005	**October 2005**	**November 2005**
Number of Participants	30	32	29
Total Urine Arsenic (µg/L)			
Mean	87.67	76.34	86.69
Median	70.09	39.94	66.24
Range	6.59 - 260.90	3.25 - 352.70	17.42 - 335.40
Inorganic Arsenic[1] (µg/L)			
Mean	32.08	23.29	23.03
Median	26.81	17.89	15.96
Range	4.13 - 91.03	2.43 - 66.28	2.91 - 65.58
[1]Inorganic arsenic is the sum of arsenous (III) acid, arsenic (V) acid, dimethylarsonic acid (DMA), and monomethylarsonic acid (MMA)			

Inorganic Urine Arsenic

Speciated urine arsenic is preferable to total urine arsenic when assessing exposure from arsenic. The speciated forms can distinguish between exposure to inorganic arsenic and its metabolites and the relatively non-toxic forms of organic arsenic, commonly found in seafood. (Kallman 1990). In this investigation, the urine specimens were analyzed for total and speciated arsenic. The inorganic arsenic fraction include arsenous (III) acid and arsenic (V) acid, and the metabolites, monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA). DMA and MMA are organic arsenic, however, they are included with the inorganic fraction because they are the metabolites of arsenous (III) acid and arsenic (V) acid.

Low levels of arsenic are commonly found in food (ATSDR 2005). Arsenic in seafood is predominantly arsenobetaine and arsenocholine, organic arsenic species, with small amounts of DMA and MMA. Much of the arsenic found in fish and shellfish is organic and does not appear to be harmful to humans and is excreted in the urine. Inorganic arsenic can be found in variable amounts in seafood, ranging from 0.1 – 41% of total arsenic (Vaessen 1989). Some varieties of seaweed have high percentages of inorganic arsenic present (Almela 2002, Laparra 2003) and can contribute to the elevation of inorganic urine arsenic (NRC 1999). In a US FDA Total Diet Study from 1991-1997, seafood contained the highest levels of arsenic, followed by rice/rice cereal, mushrooms and poultry (Tao1999). Rice, a common daily food in an Asian diet, contains inorganic arsenic and can also contribute to inorganic arsenic levels (Meharg 2008).

Inorganic urine arsenic concentrations for all participants in September, October, and November 2005 are summarized in Table 1. The mean inorganic urine arsenic levels among participants in all three testing events ranged from 32.08 µg/L to 23.03 µg/L. The highest inorganic arsenic urine level in this investigation was 91.03 µg/L in September 2005.

Retested Participants

Eight adult individuals were offered retesting of urine arsenic, and seven agreed to be retested. These individuals were offered retesting because they exceeded the screening urine level for inorganic arsenic of 20 µg/L in all three testing events. Survey results indicate that the majority of participants reported eating seafood within three days of testing. They were offered a fourth arsenic urine test because dietary sources of arsenic (seafood, seaweed, rice etc.) may have contributed to their inorganic arsenic results. Prior to testing, the participants were sent letters reminding them not to eat seafood for at least 3-5 days prior to urine collection. The letters were accompanied by pictures of seafood to avoid and a food diary to record what they ate. As an additional reminder, phone calls were made to the participants to encourage them to avoid seafood.

Testing was conducted in January 2007. The mean age of the seven retested participants was 72. Their age ranged from 44 to 88 years old. There were four males and three females.

Total Urine Arsenic

Table 2 summarizes urine arsenic concentrations for these seven retested participants during all four testing events. When retested in January 2007, the seven retested participants had similar mean total urine arsenic levels from the previous three rounds of testing (mean range: 110.51 – 125.12). The highest total arsenic urine level in this group was 238 µg/L when retested in January 2007.

Table 2. Urine arsenic concentrations for re-tested participants.

	Sept. 2005	**Oct. 2005**	**Dec. 2005**	**Jan. 2007**
Number of Participants	7	7	7	7
Total Urine Arsenic (µg/L)				
Mean	117.88	125.12	110.51	115.80
Median	128.60	135.10	82.50	87.67
Range	65.67 -179.70	30.16 – 230.60	62.36 - 203.50	16.96 – 238
Inorganic Arsenic[1] (µg/L)				
Mean	50.13	33.70	39.34	23.09
Median	53.72	34.06	38.56	28.20
Range	22.60 – 68.32	23.13 – 45.56	22.08 – 52.01	5.25 – 35.56

[1]Inorganic arsenic is the sum of arsenous (III) acid, arsenic (V) acid, dimethylarsonic acid (DMA), and monomethylarsonic acid (MMA)

Inorganic Urine Arsenic

Table 2 summarizes inorganic urine arsenic concentrations for these retested participants from September 2005, October 2005, November 2005 and January 2007. The mean inorganic urine arsenic level among these seven individuals in the fourth testing event was 23.09 µg/L (range: 5.25 µg/L – 35.56 µg/L). The mean inorganic urine arsenic level decreased over the 4 months of testing for this group. The highest inorganic arsenic urine level in the fourth round of testing was 35.56 µg/L.

Discussion

Total Urine Arsenic

Participants

As stated earlier, 50 µg/L is the comparison value for total urine arsenic with no dietary contributions. A seafood meal can result in total arsenic levels in excess of 1,000 ug/L – but this poses no health hazard (NRC 1999). The mean total urine arsenic levels among participants in all three testing events exceeded 50 µg/L (range 76.34 µg/L – 86.69 µg/L). In fact, the highest total urine arsenic level in this investigation was 352.70 µg/L. The total arsenic levels observed among participants can be attributed to the frequent and often daily consumption of seafood and seaweed in this population and the presence of organic or dietary species of arsenic in the urine of all participants, except one individual. Although, the mean total arsenic levels exceed the comparison value, the levels indicate a dietary contribution to their total urine arsenic levels. The comparison value of 50 µg/L is useful for total urine arsenic when no dietary contribution is found; this is not the case among participants in this investigation.

Dietary or organic arsenic was not detected in one individual during only one testing event, September 2005. This participant had an inorganic arsenic level of 6.59 µg/L and had no dietary or organic arsenic component detected in his urine. In a subsequent round of testing, dietary or organic was present and contributed to his total arsenic concentration. The total arsenic and inorganic arsenic urine levels for this participant did not exceed reference levels and are therefore not likely to be a health concern.

The study participants were advised not to eat seafood, fish or seaweed at least three days prior to testing. However, the majority of the study participants were Filipino whose dietary habits differ from the typical Western diet. The majority of the participants ate rice, vegetables and fish almost daily. It was difficult to get compliance to abstain from fish and seafood consumption prior to urine collections. Much intrapersonal variability for total urine arsenic is observed in Figure 1. For example, a 42 year old participant exceeded the total urine arsenic comparison value in September and October (143. 9 µg/L and 63.90 µg/L respectively) but not in November (26.52 µg/L).

Therefore, total urine arsenic levels detected above 50 µg/L may indicate a dietary source of arsenic and speciated arsenic results can confirm if dietary sources are present. In short, the total urine arsenic levels among participants in this investigation primarily reflect dietary contributions from seafood, seaweed, rice and other food sources. In general, arsenic from such food sources is not considered harmful.

Retested Participants

The mean total urine arsenic level, 115.80 µg/L, among the seven retested participants exceeded 50 µg/L in January 2007. A seafood meal can result in total arsenic levels in excess of 1,000 ug/L – but this poses no health hazard (NRC 1999). This observation can be attributed to the frequent and often daily consumption of seafood and seaweed in this population. Each individual in this group had some amount of arsenobetaine and/or arsenocholine in their urine, which indicates a dietary contribution to their total arsenic urine level. The total urine arsenic levels among the retested participants in this investigation primarily reflect dietary contributions from seafood, seaweed, rice and other food sources. In general, arsenic from such food sources is not considered harmful.

Inorganic Urine Arsenic

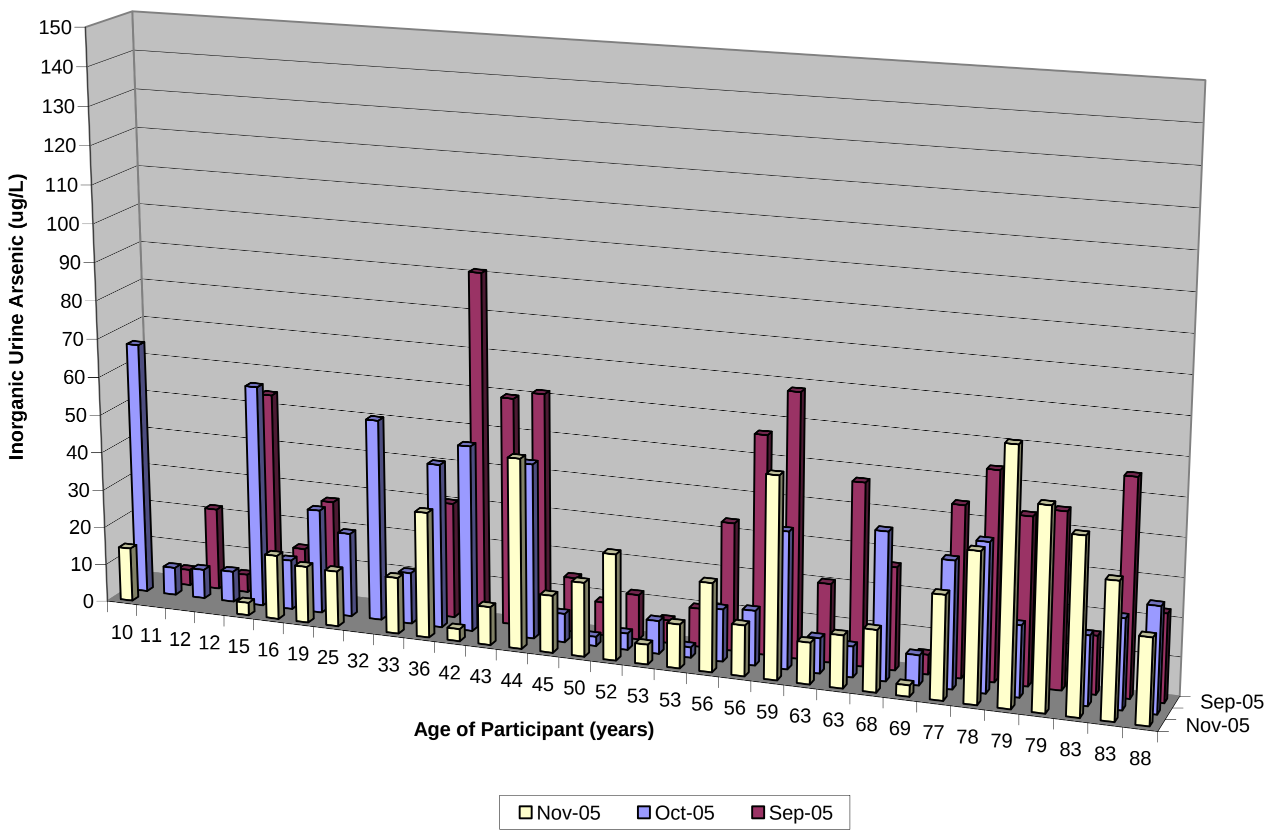
Participants

As stated earlier, 20 µg/L is the screening value for inorganic urine arsenic. The Japanese comparison value (55.27 µg/L with a standard deviation of ± 35.16 µg/L) is more appropriate as a comparison value in this population for inorganic urine arsenic because of their dietary habits. The mean inorganic urine arsenic levels among participants in all three testing events exceeded 20 µg/L. This observation may be attributed to the frequent and often daily consumption of seafood, seaweed, and rice in this population. As stated earlier, inorganic arsenic can be found in seafood from 0.1 to 41% of total arsenic (Vaessen 1989) and can contribute to the elevation of the DMA and MMA components of inorganic arsenic. These inorganic arsenic levels are similar to the Japanese inorganic arsenic levels and therefore reflect a diet that contains more seafood and other dietary sources of arsenic.

All participants, except the 7 adults who were retested, had at least one testing event with an inorganic arsenic level below 20 µg/L. In the first round of urine sampling, 19 individuals exceeded the screening level for inorganic arsenic of 20 µg/L. Fourteen exceeded the screening level in October and 12 exceeded it in November. The individuals exceeding 20 µg/L inorganic arsenic in September were not the same individuals who exceeded this value in October or November.

There was considerable intrapersonal variability in inorganic arsenic levels in the testing events. If inorganic arsenic levels had remained above 20 µg/L in all three testing events with *no* presence of dietary or organic arsenic in the urine, then an environmental source or further investigation of arsenic exposure should be considered. However, this is not the case among participants in this investigation. All participants, except one (discussed earlier), had some amount of dietary or organic arsenic in their urine, reflecting perhaps a contribution from dietary sources. Therefore, the variability is likely a result of dietary-derived arsenic that contributes to the inorganic arsenic levels. Figure 2 depicts the variability observed in each participant during each testing event for inorganic urine arsenic.

Figure 2: Inorganic Urine Arsenic in November, October and September 2005

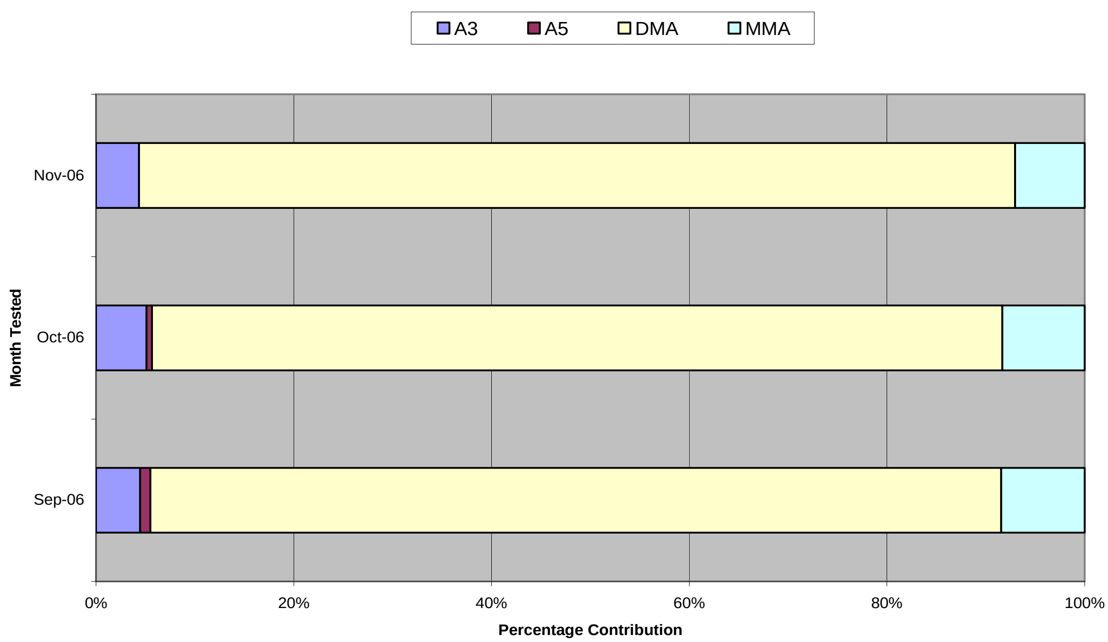


Applying the inorganic urine arsenic mean of 55 µg/L with a standard deviation of ± 35.16 (range: 20.11 µg/L – 90.43 µg/L) to the participants in this investigation is more appropriate because of similar dietary habits to the Japanese population. Six participants exceeded 55 µg/L inorganic arsenic in September, while two individuals exceeded 55 µg/L inorganic arsenic in October and one individual in November. The individuals exceeding 55 µg/L inorganic arsenic in October were not the same individuals exceeding 55 µg/L in November. Individuals in this investigation who had inorganic arsenic levels above 20 µg/L had dietary sources of arsenic present in their urine.

The highest inorganic urine arsenic level, 91.03 µg/L, in all three testing events was observed in September, this level is similar to the Japanese population comparison range (20.11 µg/L – 90.43 µg/L). This individual reported eating a seafood meal prior to urine collection and his urine arsenic levels indicated large amounts of dietary arsenic that probably contributed to his inorganic urine arsenic level. In subsequent testing events, his lowest inorganic urine arsenic was 3.23 µg/L. Therefore, this participant's inorganic urine arsenic level appears to be largely influenced by dietary habits and does not indicate unusual exposure to arsenic.

On further analysis, individuals that exceeded the screening level (20 µg/L) at any testing event have a component of organic arsenic in their urine indicating that dietary sources of arsenic contributed to their inorganic arsenic level. Figure 3 depicts the percentage contribution of arsenic species (arsenous (III) acid and arsenic (V) acid, monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA) to inorganic arsenic levels of participants during each testing event. In this investigation, more than 80% of inorganic arsenic levels in participants were primarily due to DMA.

Figure 3: Components of Inorganic Arsenic for September - November 2005



As stated earlier, other food sources that contain arsenic include rice, mushrooms, and poultry (Tao 1999). Most of the participants reported eating rice daily, a common staple of an Asian diet. Before each urine collection each participant was asked about rice consumption in the past few days. And 87% of the participants reported eating rice in

September 2005, 100% in October 2005 and 86% in November 2005. The inorganic species, DMA, arsenous (III) acid and arsenic (V) acid, are the dominant arsenic species found in white rice, the type of rice most common in Asian diets (Meharg 2008). Brown rice tends to have higher levels of inorganic arsenic than white rice; brown rice is considered unpopular in Asian diets (Meharg 2008). Currently, the amount of inorganic arsenic found in rice is not thought to pose a health risk (Tao 1999).

Also, some types of seafood and seaweed contain high levels of DMA (Yamachi 1989, NRC 1999). Many participants reported eating seaweed on a regular basis. This observation, the predominance of DMA in inorganic arsenic, appears to confirm that seafood, seaweed, rice and other dietary sources may have contributed to inorganic arsenic levels among participants that are similar to the Japanese population.

Several studies have reported that increased MMA or an elevated MMA/DMA ratio may be associated with increased risk of arsenic-associated health effects (Steinmaus 2005, Chen 2003a , and Yu 2000.) An increased percentage of MMA or an elevated MMA/DMA ratio among participants in this investigation was not observed.

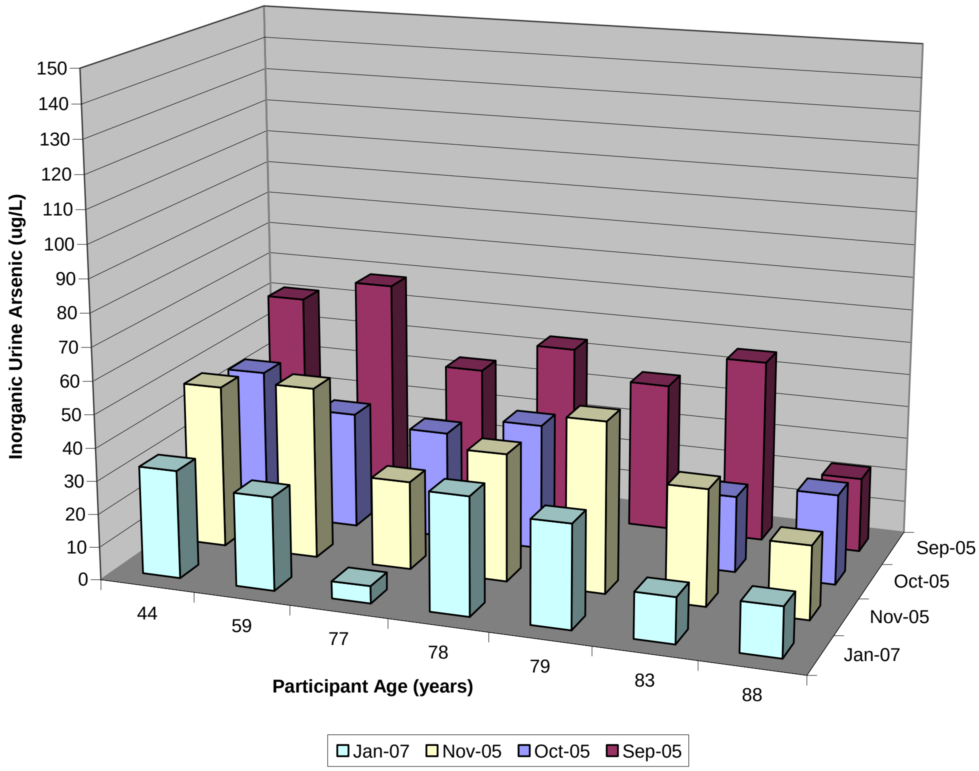
In short, the majority of participants tested for urine arsenic had arsenic levels that are similar to those detected in other populations who eat large quantities of seafood. No adverse health effects from arsenic toxicity have been reported in populations who consume large quantities of seafood. The arsenic concentrations in participants may primarily reflect dietary contributions from seafood, seaweed, rice and other food sources.

Retested Participants

Despite reminders, some participants still ate seafood or seaweed in the fourth testing event. Four out of the seven participants exceeded the screening level of 20µg/L for inorganic urine arsenic. Individuals that exceeded the screening level had a component of organic arsenic in their urine indicating that dietary sources of arsenic contributed to their inorganic arsenic level. However, none exceeded the Japanese comparison value of 55 µg/L, reflecting perhaps an effort to decrease seafood consumption for this fourth testing event. In fact, each retested participants had the lowest inorganic arsenic urine level compared to their levels in previous rounds of testing. Figure 4 depicts the declining inorganic urine arsenic levels in the retested participants during all four rounds of testing.

The highest inorganic arsenic urine level in the fourth round of testing was 35.56 µg/L. This individual in all four testing events had large components of organic arsenic in his urine indicating a dietary contribution to his inorganic urine arsenic level. This inorganic urine arsenic level still remains below the Japanese comparison level.

Figure 4: Retested Participants: Inorganic Urine Arsenic



In summary, all retested participants had urine arsenic levels that declined and had levels that are similar to populations that eat large quantities of seafood. No adverse health effects from arsenic toxicity have been reported in populations who consume large quantities of seafood. The arsenic concentrations in participants may primarily reflect dietary contributions from seafood, seaweed, rice and other food sources.

Community Garden

Although this investigation could not determine if living near arsenic contaminated soil contributed to urine arsenic levels among participants, arsenic soil levels in the community gardens are still considered elevated. Preschool children, whether they live at homes with contaminated soils or who have access to contaminated soil, have the highest potential for exposure. On the other hand, adults and older children who have access to contaminated soil probably have much less exposure because they put their hands on or into their mouths less frequently than preschool children.

Another factor that greatly affects people's exposure is the amount of soils they accidentally ingest on a daily basis. Though people might not be aware of this, everyone ingests some soil or dust every day, but some people tend to swallow more soil or dust than others. Preschool children, on average, swallow more soil and dust than people in any other age group. This is because some preschoolers often have close contact with soil and dust when they play and because they tend to engage frequently in hand-to-mouth activity. Children in elementary school, teenagers, and adults are also exposed to dusts and soils, but generally in much smaller amounts.

Because of difficulty in collecting clean urine in preschool children and the lack of appropriate comparison values, preschool children were not tested in this investigation. However their frequent hand to mouth behavior may increase their exposure to soil arsenic. Therefore, it is prudent public health to limit preschool children's access to the community gardens.

Reporting Results

In July of 2006, ATSDR/HDOH staff personally visited the participants and gave each participant their test results and an explanation of their significance was provided to the participants. An ATSDR physician was available to discuss participants' results.

The seven participants who were retested for urine arsenic received their results in the summer of 2008. An ATSDR physician was available to discuss their individual results.

Conclusions

1. This investigation could not determine if living, gardening, or playing near arsenic contaminated soil and bringing residual soil/dirt into the home from normal household activities contributed to urine arsenic levels among participants. The arsenic concentrations in participants may primarily reflect dietary contributions from seafood, seaweed, rice and other food sources. In general, arsenic from such food sources is not considered harmful.

2. The majority of adults and all children tested for urine arsenic had arsenic levels that are similar to those detected in other populations who eat regular and frequent amounts of seafood. No adverse health effects from arsenic toxicity have been reported in populations who consume regular and frequent quantities of seafood.

3. Seven adults were retested because food sources may have contributed to their test results. All retested participants had urine arsenic levels that declined and had levels that are similar to populations that eat regular and frequent amounts of seafood. No adverse health effects from arsenic toxicity have been reported in populations who consume regular and frequent quantities of seafood.

Recommendations

1. Although this investigation could not determine if living in an area with arsenic contaminated soil contributed to urine arsenic levels among participants, arsenic soil levels in the community gardens are still considered elevated. Because of continued use of the community gardens, prudent public health measures should be considered including limiting preschool children's access to the community garden.

2. ATSDR/HDOH recommends following general food safety guidelines. Additional general food safety guidelines are outlined below for home-grown fruit and vegetable consumption to reduce potential exposure to metals:

- Wash hands with soap and water after working in the garden and before eating produce from the local garden.
- Wash all fruits and vegetables to remove soil before eating.
- Peel fruits and vegetables to reduce surface contamination.
- Peel root crops (potatoes, carrots, beets, etc.).
- Discard older or outer leaves of leafy vegetables during food preparation.
- Do not compost unused plant parts, peelings, and parings for later use in a fruit and vegetable garden.

3. ATSDR/HDOH recommends the following prudent, protective land use practices to decrease future exposure to arsenic from gardening:

- Avoid putting fingers or tools in mouth when working in the community garden.
- Do not use CCA (arsenic containing) treated lumber to build raised beds.
- Avoid tracking garden soil into the home on clothes, shoes or tools.

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Acknowledgments

Michael Lewin - ATSDR, Division of Health Studies, for statistical analysis.

Kathleen Caldwell, Ph.D. and staff - Centers for Disease Control and Prevention, for arsenic laboratory analysis.