Health Consultation

EXPOSURE INVESTIGATION-II

SIMPSONVILLE/FOUNTAIN INN
(a/k/a FOUNTAIN INN SUBDIVISION)

SIMPSONVILLE, GREENVILLE COUNTY, SOUTH CAROLINA

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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:

Exposure Investigation and Consultation Branch
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Background

Testing conducted by the South Carolina Department of Health and Environmental Control (SCDHEC) in January and February 2001 indicated that elevated concentrations of uranium were present in water from some private wells in Simpsonville and Fountain Inn, South Carolina. By the end of April 2001, SCDHEC identified 30-40 wells that produced water with a uranium concentration above the Environmental Protection Agency's (EPA) drinking water Maximum Contaminant Level (MCL) of 30 micrograms per liter (µg/L). SCDHEC recommended that residents whose well water exceeded the MCL seek an alternate water source for potable use. Local health officials have been maintaining a water supply tank (water buffalo) at the local fire station since February 5, 2001, to make water from the public water system available to the residents. In addition, many residents have been buying bottled water for potable water use in their homes.

On April 25 to 27, 2001, the Agency for Toxic Substances and Disease Registry, in conjunction with SCDHEC, Division of Health Hazard Evaluation (HHE), and the SCDHEC Appalachia II EQC District Office, conducted the first Exposure Investigation (EI) in this community. The purpose of this EI was to assess human exposure to uranium from drinking water in the affected area and to better characterize radionuclide contamination in water from private wells.

The results of this investigation documented the presence of elevated concentrations of uranium in water samples from many of the private wells that were tested. In addition, the concentration of uranium in urine samples from 94 of 105 residents exceeded the 90^{th} percentile of background levels in the U.S. population. The findings, conclusions, and recommendations from this EI were presented in a previously released report [1].

Purpose of the Second Exposure Investigation

At the time that the first EI was conducted, the participants had not been drinking the water for 2 to 4 months. Therefore, the finding that urine concentrations of uranium were elevated in many of the residents indicates that significant body burdens of uranium were present from past exposures.

The second EI assessed changes in the urine uranium concentrations after the residents had not been drinking the water for an additional 6 months. If the urine uranium concentrations decreased, it would provide reassurance to the participants that uranium was being cleared from their bodies. If urine uranium concentrations increased, it could indicate that exposure was still occurring, and further efforts to identify potential sources of exposure are needed.

Site Description

Simpsonville, South Carolina is located about 12 miles southeast of Greenville, South Carolina. Simpsonville occupies 14,301 square kilometers of land, and its population in 1999 was 11,708. The population of Simpsonville is growing, and in the past few years, there has been an increase in new home construction. The town of Fountain Inn is located about 20 miles southeast of Greenville and about 6 miles from Simpsonville. Municipal water is not available to many of the homes in the area, and the water source in these homes is from a private well.

The Greenville Water District is extending public water lines to many of the affected neighborhoods. The installation of these water lines will provide the residents with a safe and dependable source of potable water. However, at the time this second EI was conducted, the public water lines were not yet operating.

Target Population

The target population for this EI was the 105 residents who participated in the first EI. Staff from the SCDHEC telephoned the residents to notify them of the second EI and set up an appointment to collect urine samples. A total of 79 residents from the first EI (75 percent) volunteered to participate in this second EI. These participants lived in 26 private homes.

Staff from the SCDHEC met with the residents to obtain written informed consent/assent from each participant and to set up appointments. SCDHEC staff gave each participant a urine specimen cup and instructed them to collect a first-morning void urine sample on the day of the appointment and to store it in a refrigerator until it was collected. SCDHEC staff also collected medical and exposure history information, which was used in interpreting the test results.

The participants ranged in age from 5 to 79 years old, and the average age was 34. At the time of this EI, the residents had not been drinking the water for 8 to 10 months. Most residents were using bottled water or water provided by the Greenville Water District. However, a few residents reported that they did occasionally drink their well water or use it for other potable purposes.

Biological Sampling and Analysis

On October 29 and 30, 2001, representatives of ATSDR and SCDHEC visited each home to collect urine samples from the participants. The urine collection cup was swirled to thoroughly mix the sample and suspend any sediment. A 4.5 milliliter aliquot of the urine was then transferred to a labeled specimen tube using a disposable pipette. During this operation, disposable latex gloves were worn. The urine specimens were stored on ice packs until they were hand-delivered to the National Center for Environmental Health Laboratory at the Centers for Disease Control and Prevention in Atlanta, Georgia for analysis.

The samples were analyzed for uranium 238 using a magnetic-sector inductively coupled argon plasma mass spectroscopy (ICP-MS). In naturally-occurring uranium deposits, uranium 238 accounts for 99.7 percent of the total mass of uranium; therefore, it is not necessary to measure the other minor uranium isotopes. To test for urinary dilution, the urine samples were also analyzed for creatinine using an enzymatic assay.

Results

The concentrations of uranium in urine samples from the 79 participants ranged from 0.008 micrograms per liter (μg/L) to 6.65 μg/L. The average urine uranium concentration was 0.376 μg/L, and the median concentration was 0.124 μg/L.

The concentration of creatinine in the urine samples was also measured. Creatinine is a metabolic product of skeletal muscle, and it is excreted by the kidneys at a constant rate regardless of the rate that urine is produced. Therefore, the urinary creatinine concentration is a measure of how concentrated or dilute the urine is.

In the following discussion, urine uranium concentrations are reported as micrograms of uranium per gram of creatinine (μg/g). The use of these units helps to reduce the variability in urine uranium concentrations due to urinary dilution. When normalized to creatinine concentration, the urine uranium concentrations in the participants of this EI ranged from 0.009 to 3.144 μg/g. The average urine uranium concentration in the 79 participants was 0.273 μg/g. By comparison, in the first EI, the average urine uranium concentration in the same 79 participants was 0.481 μg/g. The difference (decrease) in the urine uranium concentrations between the first and second EI was statistically significant, as determined using a Wilcoxon rank-sum test ($p = 0.0441$).

If the creatinine concentration is outside the normal range of 0.5 g/L to 3.0 g/L, the urine sample may be too dilute or concentrated to be reliable. The creatinine concentrations in eight of the urine samples were below 0.5 g/L. Therefore, the uranium concentrations in these samples may not be accurate. If these eight test results are not included with the rest of the population, the group average would be minimally affected (0.273 μg/g vs. 0.266 μg/g). The following discussion and analyses include all 79 of the test participants.

To evaluate changes in the urine uranium concentrations, the concentrations from this EI were plotted against the concentrations from the first EI (Figure 1). The solid line represents where the data points would have plotted if there had been no change in the urine uranium concentrations between the first and second EIs. Data points lying below the line represent individuals whose urine uranium concentrations decreased between the first and second EI; data points lying above the line represent individuals whose urine uranium concentration increased.

The urine uranium concentrations decreased in 50 of 79 (63%) of the participants and increased in 29 of 79 (37%) of the participants. Most of the increases in urine uranium concentrations were small (less than 2-fold), and/or the second urine uranium concentration was less than 0.5 μg/g. However, urine uranium levels increased significantly in a few individuals, even though they reported no recent consumption of well water. The maximum increase was observed in an adult woman whose urine uranium concentration increased 18-fold from the first to the second EI.

Based on data from the Nutrition Examination Survey conducted in 1999, the Centers for Disease Control and Prevention reported that urine concentrations of uranium in the general population were as follows [2]:

	Percentile			
	25th	50th	75th	90th
U concentration (µg/g creatinine)	<LOD	0.005	0.011	0.024

LOD = Limit of Detection (0.004 µg/g creatinine)

The concentration of uranium in urine samples from 71 of 79 residents (90%) exceeded the 90th percentile of the general population. Therefore, even though the urine uranium concentrations decreased in most of the residents, the concentrations remained significantly elevated. As discussed below, the elevated urine uranium concentrations could be the result of previous chronic exposure to uranium which accumulated in the body and is now being slowly excreted.

Discussion

Only a small fraction of uranium that is ingested is absorbed through the gastrointestinal tract into the body. For uranium in food or drinking water, it has been estimated that 0.3 to 6 percent of the ingested uranium is absorbed [3]. Once absorbed into the systemic circulation, the uranium deposits primarily in the bones, with lesser amounts depositing in the kidney, liver, and other soft tissues.

The elimination of uranium from the body is complex and involves multiple compartments and transfer rates [4]. In an early study (conducted in the 1940s), uranium was intravenously injected into human subjects [3]. About two-thirds of the injected uranium dose was excreted over the first 24 hours, and about 75 percent was excreted within 5 days. Of the remainder, most was slowly excreted over a period of several months, but a small portion was retained and excreted over a period of years.

In the two EIs, the urine samples were collected at time periods of 2-4 months and 8-10 months after the participants reported that they had stopped drinking the water. Therefore, in the absence of ongoing exposure to uranium, the urine uranium detected in the EI participants is likely due to uranium that is being slowly released from bone and other tissue storage sites in the body. The uranium concentrations in the urine should gradually decrease as the body storage sites become depleted and reach a new, lower steady-state equilibrium.

The urine uranium concentrations decreased in the ten individuals from the first EI with the highest urine uranium concentrations (greater than 1.0 µg/g). Among these ten individuals, urine uranium concentrations decreased an average of 78 percent between the first and second EI (6-month time interval).

Among the EI participants with initial urine uranium concentrations below 1.0 µg/L, the decreases in urine uranium concentrations were generally smaller, and in some individuals, the concentrations increased (Figure 1). In people with low urine uranium concentrations, background exposure to uranium in the diet could cause fluctuations in daily urine uranium concentrations. In a normal population with no unusual exposure to uranium, creatinine-normalized concentrations of uranium in spot urine samples were reported to vary as much as 2-fold [5]. In people with high body burdens of uranium, diurnal variability in urine uranium concentrations is much less [6]. This lower diurnal variability could be due to the relatively small contribution of dietary uranium to a high body burden.

Large increases in urine uranium concentrations were observed in a few individuals. The largest increase occurred in an adult woman whose urine uranium concentration increased 18-fold to a concentration of 3.1 µg/g. This large increase suggests recent exposure to a significant source of uranium or an increase in the rate of excretion. Additional investigations are warranted to identify possible sources of uranium exposure in such individuals. These investigations should also include taking a detailed medical history to identify conditions that might contribute to an increase in urine uranium.

The health impact, if any, of the observed body burdens of uranium is not known. Studies of workers with occupational exposure to uranium have not demonstrated convincing epidemiological evidence of serious renal disease or other health effects [7]. However, these studies had limited statistical power to detect an increased rate of disease, if it had been present. Also, the "healthy worker effect" may have excluded those with pre-existing kidney disease.

The Nuclear Regulatory Commission has recommended that corrective actions be taken when urine uranium concentrations in uranium mill workers exceed 15 µg/L [8]. None of the participants' urine uranium concentrations exceeded this concentration. However, the participants' urine uranium concentrations were probably higher in the past, while they were drinking the water. Furthermore, standards for occupational exposures are derived for healthy adult workers and may not be protective of more sensitive members of the general population. In particular, people with pre-existing renal disease, or people taking potentially nephrotoxic medications (such as aminoglycoside antibiotics), may be more susceptible to the nephrotoxic effects of uranium.

Although exposure to high doses of uranium can damage the kidneys, animal experiments indicate that once the exposure stops, the damage may be reversible [5]. Therefore, early signs of renal toxicity due to uranium exposure may not be detectable months after exposure has stopped. Nevertheless, it would be prudent for the participants in this EI to alert their physicians of their elevated exposures to uranium, so appropriate medical evaluations can be conducted, if warranted.

Kidney Biomonitoring Testing

Exposure to uranium can damage the proximal tubule of the kidney. Damage to this portion of the tubule impairs the ability of the nephron to reabsorb low molecular weight proteins from the urine. Therefore, the appearance of elevated concentrations of low molecular weight proteins, such as retinol binding protein, in the urine is an early marker of damage to the kidney.

In conjunction with the urine uranium testing, SCDHEC conducted a separate test, in which urine samples were analyzed for retinol binding protein. The results of this investigation will be reported by SCDHEC in a separate health consultation.

Reporting Results

ATSDR/SCDHEC provided the participants with their individual test results and an explanation of their significance. ATSDR and SCDHEC also provided toll-free telephone numbers so the participants and their health care providers could contact ATSDR and SCDHEC to further discuss their test results.

Conclusions

(1) Urine uranium concentrations were significantly elevated in 90 percent of the EI participants.

(2) Urine uranium concentrations decreased in most (63%) of the EI participants. In the ten participants with the highest initial urine uranium concentrations, the concentrations decreased an average of 78 percent.

(3) Urine uranium concentrations increased in 37% of the participants. For most of these individuals, the increase in the urine uranium concentration was small, and /or the final concentration was less than 0.5 μg/g.

(4) Large *increases* in urine uranium concentrations were observed in four participants (greater than a 2-fold increase to a final concentration greater than 0.5 μg/g).

Recommendations

(1) Residents with uranium-con*taminated* wells should continue to use alternate sources of water for potable use until public water is available or an appropriate water treatment system has been installed.

(2) Individuals with health concerns over exposure to uranium should consult with their personal physician. ATSDR and SCDHEC physicians are available to discuss individual test results with health care providers.

(3) Conduct in-depth questionnaires and environmental testing to identify other potential sources of uranium exposure in homes where the residents' urine uranium concentrations substantially increased.

Public Health Action Plan

(1) SCDHEC will submit a proposal to obtain funding from ATSDR to conduct a community Health Investigation. This study will assess the health impact of exposure to uranium from drinking water on the residents of Simpsonville/Fountain Inn.

(2) ATSDR and SCDHEC will develop educational materials on the health effects of exposure to uranium and medical testing for uranium-related disease. Relevant information will be developed in printed and electronic formats for the general public and health professionals.

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Figure 1: Urine uranium (EI 1) vs. (EI 2)