Health Consultation

EXPOSURE INVESTIGATION

FOUNTAIN INN/SIMPSONVILLE AREA
(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:

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Background

Testing conducted by the South Carolina Department of Health and Environmental Control (SCDHEC) since January 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 ($\mu g/L$). 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. However, it was not certain if all residents were using an alternate water source for potable purposes. Therefore, 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 this Exposure Investigation (EI). 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 from this investigation were used to identify appropriate follow-up public health actions for the participants. The results of this investigation are applicable only to the participants of the investigation and are not generalizable to other individuals or populations.

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. Homes in the area range in age from less than 5 to 20 years old. Municipal water is not available to many of the homes in the area, and the water source in these homes is a private well.

Target Population

The target population for this EI was residents who currently live in or near Simpsonville or Fountain Inn. A household was eligible to participate if previous testing at the home identified uranium contamination in well water in excess of 30 μg/L.

Staff from the SCDHEC initially contacted the residents by telephone to notify them of the EI and set up an appointment to collect environmental (water) and biological (urine) samples. The following week, staff from the SCDHEC met with eligible residents to distribute necessary materials. A urine specimen cup was provided to each member of the family who participated in the biological testing. The participants were instructed 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. Each participant was required to complete a written informed consent/assent form for environmental and biological testing.

Three "control" homes where previous testing demonstrated a low uranium concentration in the water were also included in the EI. Urine samples were not collected from residents of the control homes.

Environmental and Biological Sampling

Environmental and biological sampling were conducted on April 25 and 26, 2001. A team consisting of staff from ATSDR and SCDHEC visited each home to collect biological and environmental samples.

Environmental Sampling and Analysis

A 1-gallon water sample was collected from the kitchen faucet after running the tap for 2-3 minutes. If the kitchen tap had an attached water treatment or filtration device, or if a whole house water treatment system had been installed, an attempt was made to collect a second water sample before it entered the water treatment system. If the residents were no longer using their private well for potable water, a sample of their current potable water source (bottled water) was also collected, if available.

At selected homes, an additional water sample was collected and analyzed for radon according to approved EPA protocols. For these analyses, duplicate water samples were collected at the well head or at the tap closest to the well head. A well water radon test was conducted if: (1) the owner indicated that previous testing had detected an elevated radon concentration in well water, (2) radiation levels, as measured with a Ludlum microroentgen meter, were greater from a 5-gallon bucket of water than from background soil, or (3) high radon concentrations were reported in neighboring wells.

ATSDR staff hand-delivered the water samples to the Georgia Institute of Technology, Environmental Resources Center (GT-ERC), in Atlanta, Georgia for analysis. At the GT-ERC, water samples were tested for uranium 234, 235, and 238 using alpha spectroscopy. The ten water samples with the highest uranium concentrations were further tested for radium 226 by radon emanation. The same ten water samples were analyzed for cesium 137 and radium 228 using gamma-ray spectral analysis. Radon was measured by liquid scintillation counting of duplicate samples.

At one house, the residents requested that home-grown fruits and vegetables that they canned be tested for uranium. One-quart samples of the home-canned tomatoes and peaches were dried at 110 °C, then ashed, and analyzed for uranium isotopes.

Biological Sampling and Analysis

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). The urine samples were also analyzed for creatinine using an enzymatic assay.

Results

Environmental sampling

Uranium

Uranium concentrations were measured in well water samples from 39 homes. The total uranium concentrations in tap water samples ranged from not detected (< 0.5 picocuries per liter [pCi/L]) to 5,830 pCi/L. In many homes, sediment filters were installed on the main water line entering the house; these filters were not effective in removing uranium from the water. This finding is expected, since uranium in water is usually present as the soluble uranyl ion (UO^{+2}), which would not be removed by a particulate filter.

The drinking water standard for uranium is expressed as a mass concentration (i.e., 30 µg/L). Therefore, to facilitate comparison, the uranium concentrations in water were converted to mass concentrations. If expressed in mass units, the uranium concentrations ranged from not detected to 7,780 µg/L, with a mean uranium concentration of 521 µg/L and a median concentration of 67 µg/L.

The ratios of the concentrations of uranium isotopes in the water samples were within the range of the ratios found in naturally-occurring uranium. Therefore, the uranium in ground water appears to be derived from naturally-occurring geologic deposits.

Alternate water sources that residents were using as a potable water supply were also tested for uranium. These sources consisted of water from the public water system (collected at the water buffalo at the Canebrake Volunteer Fire Department) and three commercial sources of bottled water (Culligan, Le Bleu, and Carolina Mountain). No uranium (detection level of 0.5 pCi/L) was detected in any of the alternate water sources. The uranium concentrations in water samples from the three "control" homes ranged from non-detected to 3.9 pCi/L.

Uranium concentrations were also measured in a jar of home-canned peaches and tomatoes provided by one resident. The uranium concentration in the peaches was 0.429 pCi/g or 0.526 µg/g (wet weight) and in the tomatoes, 0.632 pCi/g or 0.777 µg/g (wet weight).

Radon

Radon was detected in water samples from all 17 wells tested. The average radon concentration in duplicate water samples from each well ranged from 1,650 to 195,000 pCi/L. The mean radon concentration detected in the water samples was 27,900 pCi/L, and the median concentration was 12,000 pCi/L.

Radium

Radium 226 concentrations in water samples from 10 wells ranged from 0.1 to 24 pCi/L. The mean radium concentration was 3.5 pCi/L, and the median concentration was 1.2 pCi/L. Radium 228 was not detected (< 5 pCi/L) in water samples from any of the 10 wells.

Biological Sampling

Urine samples from 105 residents were tested for uranium 238. Uranium was detected in 104 of 105 samples (detection limit of 0.004 µg/L). The urine concentrations ranged from non-detected to 9.55 µg/L. The mean uranium concentration was 0.508 µg/L, and the median concentration was 0.162 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 how dilute the urine is.

When normalized to creatinine concentration, the urine uranium levels ranged from non-detected to 2.7 µg/g creatinine. The mean uranium concentration was 0.40 µg/g creatinine, and the median concentration was 0.139 µg/g creatinine.

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 11 of the urine samples were below 0.5 g/L, and the creatinine concentrations in two of the samples were above 3.0 g/L. Therefore, the uranium concentrations in these samples may not be accurate.

Discussion

The concentrations of uranium and radon detected in water samples from many of the wells tested exceeded the Environmental Protection Agency's (EPA) Maximum Concentration Limits (MCL). MCLs are health and technology based standards that are legally enforceable for public water systems. MCLs are not legally enforceable for private wells. Nevertheless, in order to be protective of public health, it is recommended that contaminant levels in water from private wells should not exceed MCLs.

Uranium

Chronic exposure to high concentrations of uranium in drinking water can result in the accumulation of uranium in the kidneys, which can damage the proximal tubules. Uranium is potentially harmful to the kidneys because of its chemical toxicity, not because of its radioactivity. The EPA set a MCL of 30 µg/L for uranium in drinking water to protect humans from the toxic effects of uranium on the kidneys.

Residents with contaminated wells can ingest uranium in water that is used for drinking or food preparation. Gastrointestinal absorption of uranium is low - 1% of soluble salts and less than 1% of insoluble compounds [1]. Uranium is not volatile, so inhalation exposures are not of concern.

Uranium concentrations in well water samples from 26 of 39 (67 %) homes exceeded the MCL. This finding is expected since most of the homes were selected because previous testing by the SCDHEC had indicated that water from the wells had elevated uranium concentrations.

Uranium concentrations were also elevated in urine samples from many of the residents. In the National Health and Nutrition Examination Survey, which was conducted in 1999, the Centers for Disease Control and Prevention reported that the 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 94 of 105 residents (90 %) exceeded the 90th percentile of the comparison population. These results indicate that the population tested has had significant exposure to uranium. Since none of the people tested reported any exposure to uranium through occupational or other known sources, the likely source of exposure is through consumption of contaminated ground water.

The pharmacokinetics of absorbed uranium in the body is complex and involves multiple compartments and transfer rates, even within the same tissue [3]. The major storage site for uranium in the body is the skeleton, although an appreciable fraction of absorbed uranium is taken up by the kidneys, liver, and other soft tissues.

At the time this EI was conducted, the residents had been aware of the water contamination for 1 to 3 months. Most of them reported that they were not drinking their well water and were using an alternate potable water source. Therefore, it is likely that the uranium detected in the urine samples was derived from uranium stored in the body, which was being slowly released.

The health impact, if any, of past exposures to uranium in drinking water is not known. Studies of workers with occupational exposure to uranium have not demonstrated convincing epidemiological evidence of serious renal disease [1]. However, these studies had limited statistical power to detect an increased rate of disease, if it had been present.

For occupational exposures, the Nuclear Regulatory Commission issued a standard for corrective action when urine uranium concentrations exceed 15 µg/L [4]. 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.

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]. Individual test results from this EI were provided to the personal physicians of the participants upon request. The participants should consult with their physician to decide if further medical evaluation is warranted.

Uranium concentrations were also measured in a jar of home-canned peaches and tomatoes provided by one resident. The uranium concentration in the peaches was 0.429 pCi/g or 0.526 µg/g (wet weight) and in the tomatoes, 0.632 pCi/g or 0.777 µg/g (wet weight). By comparison, the uranium concentration in well water from this residence was higher at 2.75 pCi/g (or 2,748 pCi/L).

The uptake of uranium from soil by garden vegetables and fruits is reported to be low; however, some adsorption onto root vegetables can occur [6,7]. The uranium in the canned produce could have resulted from uranium contamination of the produce or from water used in the canning process. The risk posed by eating these foods would depend on the rate of consumption. For illustrative purposes, it was assumed that an adult would eat 1 cup (237 milliliters) of canned peaches per day. The uranium ingestion rate for this scenario would be:

$$(0.526\ \mu g/g)\ \times\ (237\ \text{grams})\ \div\ (70\ \text{kg bodyweight})\ =\ 1.78\ \mu g/kg/day$$

This estimated uranium dose is slightly less than ATSDR's intermediate and chronic Minimal Risk Level (MRL) for uranium of 2 µg/kg/day. By comparison, daily ingestion of 1 cup of canned tomatoes a day would yield an estimated dose of 2.63 µg/kg/day, which slightly exceeds the MRL.

Therefore, the risk posed by consumption of these canned foods would depend on how much is eaten and how often they are eaten. To be protective of public health, ATSDR recommends that consumption of these foods be limited to occasional meals of moderate-sized portions ($\leq$ 1 cup).

Radon

Radon 222 is a radioactive gas that is produced by the radioactive decay of radium 226, which, in turn, is produced in the radioactive decay series of uranium 228. For community water systems, the EPA has proposed a drinking water MCL of 300 pCi/L for radon.

The EPA has suggested that ingestion of water with a high concentration of radon may cause a slight increase in the risk of stomach cancer [8]. However, radon gas, which escapes from water into air inside the house, poses a greater health risk. Radon and its radioactive decay products can be inhaled into the lungs and cause an increased risk of lung cancer. This lung cancer risk is enhanced in people who smoke cigarettes.

The water concentration of radon exceeded 300 pCi/L at 17 of 17 wells tested, and the highest radon concentration was 195,000 pCi/L. High concentrations of radon may pose a health hazard to residents from long-term inhalation exposures to radon that escapes from water into indoor air. Such exposures are particularly likely to occur during showering. Indoor air inhalation exposures to radon can be reduced by increasing indoor-outdoor exchange, especially in the bathroom. In addition, radon can be removed from water using activated carbon filters. However, the use of such filters requires periodic monitoring and maintenance. Furthermore, exposure to gamma radiation from radionuclide buildup on the filter may pose a hazard, and spent filters must be safely disposed of [9].

Radium

Radium 226 concentrations in water samples from 10 wells ranged from 0.1 to 24 pCi/L. Radium 228 and cesium 137 were not detected in water samples from any of the 10 wells.

Radium 226 is a decay product of the uranium series, whereas radium 228 is a decay product of the thorium series. In addition, uranium and thorium have different geochemical behaviors and solubilities. Therefore, it is possible for one of the radium isotopes to be present in the absence of the other.

In public water systems, the EPA's MCL for combined radium 226 and 228 is 5 pCi/L. This concentration was exceeded by a water sample from one well (24 pCi/L); water from this well also exceeded the uranium MCL. The radium concentrations in water from the other nine wells were 3.7 pCi/L or less. Radium is taken up by the skeleton where its radioactive decay may increase the risk of bone cancer. Therefore, long-term exposure to radium in drinking water at concentrations in excess of the MCL may pose a health hazard.

Reporting Results

ATSDR/SCDHEC mailed the participants their individual test results. Toll-free numbers were provided so the participants could call ATSDR/SCDHEC staff to further discuss their test results.

Test results were also mailed to the participant's personal physician, if requested. The resident's personal physician can consult with ATSDR/SCDHEC physicians concerning their patient's individual test results and follow-up medical management.

ATSDR/SCDHEC staff developed informational materials for distribution to the local medical community. A SCDHEC physician will meet with local physicians to present information about health effects of uranium, radium, and radon and to share information about the EI.

Conclusions

(1) Concentrations of uranium and radon in excess of drinking water standards were detected in water samples from private wells.

(2) The radionuclide contamination of the groundwater appears to be naturally occurring.

(3) Elevated concentrations of uranium were detected in urine samples from 90 percent of the participants in this exposure investigation.

(4) The health impact, if any, of exposure to radionuclide contamination in water from the private wells is not known.

Recommendations

(1) Seek an alternate water source for potable water in those homes where the uranium concentration exceeds the drinking water standard (or implement treatment with adequate maintenance and monitoring).

(2) Seek an alternate water source for potable and non-potable water in those homes where the radon concentration exceeds the drinking water standard (or implement treatment with adequate maintenance and monitoring).

(3) Residents with elevated urine uranium levels should consult with their personal physician to discuss whether any follow-up medical evaluation is warranted.

(4) Provide health education to the community on how to reduce exposure to radionuclide contamination in well water.

(5) Provide information to the residents and health care providers on the potential health effects of exposure to uranium and radon.

(6) After the State has completed their geological survey, test other potentially impacted wells in the affected area for uranium and radon contamination.

Public Health Actions

(1) ATSDR will participate in a public availability session hosted by SCDHEC. At the meeting, staff from SCDHEC and ATSDR will be available to respond to questions the participants may have regarding their test results.

(2) ATSDR will consult with SCDHEC to determine if a follow-up Exposure Investigation to further evaluate exposed residents is warranted.

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