Uranium

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Abstract

A developing uranium source map. The current toxicology chapter provides limited context; a dedicated synthesis remains incomplete.

This page draws on 9 peer-reviewed studies and 2 other cited sources. The complete citation list is at the bottom of the page.

1 | Overview

Uranium is listed among minor toxic metals for which toxicity has been described 1. That textbook chapter does not provide a detailed uranium subsection 1.

Uranium occurs naturally in the earth's crust and in surface water and groundwater, and it is highly soluble in soft, slightly alkaline bicarbonate water under oxidizing conditions, which is why wells drilled into uranium-rich granite can carry very high levels 2. The human evidence on this page comes mainly from groundwater used for drinking in Finland, Kazakhstan and India 2 3 4. Animal and occupational studies reviewed by Finnish investigators point to chemical kidney toxicity, rather than a radiation hazard, as the major health effect of uranium 2.

Two forms recur in the cited work. Natural uranium is what people drink in well water; its isotope ratios distinguish it from fallout or industrial material 3. Depleted uranium, with a lower uranium-235 share, appears here only in laboratory toxicology studies 5 6 7.

2 | Toxicology

Kidney

In 325 people in southern Finland who had drunk water from drilled bedrock wells for an average of 13 years, urinary uranium was associated with higher fractional excretion of calcium and phosphate, markers of proximal tubule function 2. Each 1 µg/mmol creatinine increase in urinary uranium was linked to a 1.5% (95% CI 0.6 to 2.3) rise in calcium fractional excretion and a 13% (1.4 to 25) rise in phosphate fractional excretion 2.

Phosphate fractional excretion was significantly higher at water uranium above 300 µg/L than below 2 µg/L 2. The association showed no clear threshold, while creatinine clearance and urinary albumin, which reflect glomerular function, were not associated with exposure 2. The authors state that the clinical and public health relevance of these changes is not easily established 2.

Bone

In long-term exposure, uranium accumulates in bone and kidney, and the uranyl ion is thought to exchange with calcium at the surface of bone mineral 8. In 288 adults from the same Finnish well-water cohort, there was a suggestion that the bone resorption marker CTx ($p = 0.05$) and osteocalcin ($p = 0.19$) rose with uranium exposure in men, with no similar pattern in women 8. The authors conclude that bone may be a target of uranium's chemical toxicity in humans and that more detailed evaluation is needed 8.

Cellular mechanisms

Early laboratory work showed that uranyl nitrate binds reversibly to proteins and inhibits glucose fermentation and oxidation in living yeast, an effect the authors attributed to binding at the protein layer of the cell membrane 9. In Atlantic salmon exposed for 48 hours to 0.25 to 1.0 mg/L depleted uranium in water, liver gene responses pointed to mitochondrial function and oxidative stress pathways, although no micronuclei or plasma stress changes were found 6. A preprint that has not been peer reviewed reports reduced movement and delayed hatching in zebrafish larvae at 18 ppb depleted uranium, with lower cellular reductive capacity that did not depend on reactive oxygen species 7.

Inhalation and the brain

Rats that inhaled a uranium tetraoxide aerosol for 30 minutes had higher uranium than controls in every brain region tested 4 hours later, with the highest levels in the olfactory bulbs and a front-to-back gradient 5. Microscopy located uranium along olfactory neuron dendrites, between epithelial cells and in olfactory nerve bundles, consistent with direct nose-to-brain transport 5. The study used a single 30-minute exposure and reported no functional neurological outcomes 5.

Radiological dose

Studies that modeled radiological dose from drinking well water found values below the 100 µSv per year reference cited by the authors: 1.0 to 18.7 µSv per year for adults near the Semipalatinsk test site 3, and mean annual ingestion doses of 49.30 and 56.34 µSv per year for infants aged 0 to 6 and 7 to 12 months in arid western India 4. In the Indian study the modeled chemical hazard quotient had a mean of 0.78, below unity 4.

3 | Typical exposure routes

Drinking water (water) from private or community wells is the best-documented route in the cited evidence 2 3 4. In Finland, about one-seventh of the population was reported to use drinking water above 2 µg/L, and some wells reach 12,000 µg/L 2. Around the Semipalatinsk test site, isotope ratios showed that elevated well-water uranium was natural and came from rock weathering, not test fallout 3. In western India, dissolution of the uranium vanadate mineral carnotite, water-rock interaction and evaporation drove enrichment, and high-uranium groundwater was saline sodium chloride water with high dissolved solids 4.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
2, southern Finland	Drilled-well drinking water, cross-sectional, 1999	total uranium	median 28 µg/L (IQR 6 to 135; max 1,920)	325	Wells selected to span a wide exposure range, so not a population prevalence
2, southern Finland	Daily intake from drilled-well water	total uranium	median 39 µg/day (IQR 7 to 224)	325	Intake derived from reported water volume and measured concentration
8, southern Finland	Drilled-well drinking water, bone marker subcohort	total uranium	median 27 µg/L (IQR 6 to 116)	288	Subset of the same cohort, not an independent sample
3, Semipalatinsk region, Kazakhstan	Drinking well water, alpha spectrometry	uranium-238	0.3 to 28.7 µg/L (3.6 to 356 mBq/L)	35	Few wells per settlement; mass converted from activity by the authors
3, Irtysh River, Kazakhstan	River surface water, comparison	uranium-238	2.5 to 3.0 µg/L	not stated	Single river comparison
4, western Rajasthan and northern Gujarat, India	Groundwater from wells, tube-wells and taps, LED fluorimetry	total uranium	0.6 to 260 µg/L, mean 24.0 µg/L	265	Abstract and results disagree on the share above 30 µg/L

Food grown near a uranium mine is a second route documented here, at low wet-weight levels (see Food sources) 10. Inhalation of uranium dust is described as the main cause of contamination in nuclear occupational activities 5. Surface soil around a prospective uranium mine in Inner Mongolia had a mean uranium-238 activity of 25.81 Bq/kg dry weight before mining began, below the Chinese and world means cited by the authors 11.

4 | Food sources

The only food measurements in the cited evidence come from produce grown within 25 km of the Tummalapalle uranium mine in Andhra Pradesh, India 10. Uranium was the lowest-concentration element of 13 measured, ranging from 1.7 to 27.6 µg/kg wet weight across 72 samples, and the median intake from 100 g a day of these vegetables and fruits was estimated at 0.6 µg per day 10. No site away from the mine was sampled, so the study cannot show whether the mine raised produce uranium 10.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION

10, Tummalapalle, India	Tomato, core and buffer zones	total uranium	2.7 and 4.1 µg/kg, wet weight (zone means)	not stated	Per-group n not reported; no distant control
10, Tummalapalle, India	Green chilli (peppers), core and buffer zones	total uranium	8.0 and 4.4 µg/kg, wet weight (zone means)	not stated	Highest vegetable mean, core zone
10, Tummalapalle, India	Bitter gourd (vegetables), core and buffer zones	total uranium	4.4 and 4.4 µg/kg, wet weight (zone means)	not stated	No zone difference
10, Tummalapalle, India	Banana, core and buffer zones	total uranium	16.4 and 5.3 µg/kg, wet weight (zone means)	not stated	Highest mean of all crops, core zone, wide SD
10, Tummalapalle, India	Papaya (fruit), core and buffer zones	total uranium	6.8 and 10.6 µg/kg, wet weight (zone means)	not stated	Buffer zone higher than core zone
10, Tummalapalle, India	Sweet lime (fruit), core and buffer zones	total uranium	5.4 and 4.0 µg/kg, wet weight (zone means)	not stated	Low and similar between zones

The cited evidence does not establish uranium levels in staple foods, infant foods or market baskets, and it does not compare food with drinking water as a share of total intake.

5 | Regulatory limits

The cited papers quote drinking-water values rather than food limits. The provisional WHO guideline for uranium in drinking water is 30 µg/L, and India's Atomic Energy Regulatory Board set a radiological limit of 60 µg/L in 2004, while the Bureau of Indian Standards has set no limit 4 (WHO drinking-water guidelines). The United States EPA maximum contaminant level for uranium in drinking water is 30 µg/L 7 (US EPA drinking-water standards).

Earlier WHO values were lower. At the time of the Finnish kidney study, WHO had proposed a guideline value of 2 µg/L based on animal experiments in the absence of human data, and proposed guideline values ranged from 2 to 100 µg/L 2. A restrictive proposed WHO guideline of 15 µg/L from the third edition was used as the comparison for Kazakh well water 3. The Finnish authors suggested that the safe concentration may lie within the proposed range of 2 to 30 µg/L 2.

For chemical toxicity, the Indian study compared its lifetime average daily dose (mean 0.47 µg/kg body weight per day) with reference doses of 0.6 µg/kg per day from WHO and 4.4 µg/kg per day from the Atomic Energy Regulatory Board 4. For radiological dose, the reference value cited for drinking water is 100 µSv per year 3. The cited evidence does not establish any maximum level for uranium in food.

6 | Testing

Inductively coupled plasma mass spectrometry (ICP-MS) was used for uranium in water and urine, with detection limits of 0.0004 µg/L in water and 0.002 µg/L in urine, split-sample checks and inter-laboratory comparison 2. It was also used for produce digested in nitric and perchloric acids 10 and for rat brain tissue 5. Other methods in the cited work are alpha-particle spectrometry after radiochemical separation with a uranium-232 yield tracer 3, LED fluorimetry of uranyl complexes with a detection limit of 0.2 ppb 4, and gamma spectrometry that infers uranium-238 activity in soil from a thorium-234 line 11.

Urinary uranium tracks drinking-water uranium closely: in the Finnish cohort the correlation between water and urine concentrations was 0.85, and each additional 1 µg of daily intake was associated with 0.21 ng/mmol creatinine more uranium in urine 2. Isotope ratios identify the source of uranium: a uranium-235 to uranium-238 activity ratio near 0.046 marked natural uranium in Kazakh wells 3, and a uranium-235 share of 0.4% rather than 0.7% confirmed that brain uranium in exposed rats came from depleted test material 5.

7 | Microbiome effects

The cited evidence does not establish effects of uranium on the gut or other human microbiomes. The only microbial work cited is a 1948 laboratory study showing that uranyl nitrate inhibits glucose metabolism in yeast and some bacteria, which says nothing about microbial communities in people 9.

8 | Vulnerable populations

Infants had the highest modeled annual ingestion doses from groundwater in arid western India, with means of 49.30 µSv per year at 0 to 6 months and 56.34 µSv per year at 7 to 12 months 4. People who rely on private drilled wells in uranium-rich bedrock form the exposed group in the Finnish studies 2. In the bone study, the suggested effect was seen in men but not in women 8. Workers in nuclear fuel-cycle operations, mines and dismantling are described as exposed through airborne uranium particles 5. The cited evidence does not establish effects in pregnancy; pregnant women were excluded from the Finnish kidney study 2.

9 | Mitigation

The cited evidence does not establish how well any treatment removes uranium from water or food. The Finnish kidney study excluded households that had effective equipment for removing uranium from their well water, but it reports no removal performance 2.

10 | Open questions

- Uranium in staple foods, infant foods, bottled water and total diets is not covered by the cited evidence.
- No cited study compares food and drinking water as shares of total uranium intake.
- Removal of uranium by household water treatment, municipal treatment or food processing is not established.
- Whether the proximal tubule changes linked to drinking-water uranium progress to clinical kidney disease is not established.
- Bone effects in humans rest on one cross-sectional analysis with borderline significance and a sex difference that is not explained.
- Effects of uranium on the gut microbiome are not established.
- Effects in pregnancy and early childhood are not measured; infant evidence is limited to modeled doses.

- Whether a uranium mine raises uranium in nearby produce is not established, because the produce study had no distant control site.
- Food limits for uranium are not stated in the cited evidence.

11 | Frequently asked questions

In which foods and beverages has uranium actually been measured?

The sources mapped on this page report uranium occurrence across a wide range of foods and beverages, including commercial milk and infant formulas (Largueza et al. 2026, Almeida et al. 2022), ready-to-eat baby purees (Henríquez-Hernández et al. 2023), rice (Gama et al. 2025), coffee beans (Albals et al. 2021), and edible seaweeds (Mosusu 2023). The page catalogs these as occurrence sources; it does not yet synthesize concentration values.

Is uranium in drinking water something researchers track?

Yes. Several sources mapped here assess uranium in drinking water, including a global review of heavy metals in drinking water (Olowoyo et al. 2026), a US contaminants review (Levin et al. 2024), and analyses of uranium in US community water systems (Ravalli et al. 2022, Martinez-Morata et al. 2022). The page lists these as occurrence and exposure sources rather than summarizing their findings.

Do any regulators set limits or monitoring programs for uranium in food or water?

The regulatory sources mapped here address uranium in several ways. The WHO drinking-water guidelines derive guideline values for uranium among other contaminants (WHO 2022), the FDA runs a compliance program covering uranium surveillance in food and foodware (FDA 2025) and includes uranium in its Total Diet Study (FDA 2022), and Hong Kong's Centre for Food Safety sets maximum levels for uranium as one of its metallic contaminants (Centre for Food Safety 2019). This page does not reproduce the specific limit values.

Are infants and pregnant women covered in the uranium literature here?

Yes. The mapped sources include uranium in infant formula and baby purees, infant birth-cohort dietary exposure (Signes-Pastor et al. 2022), infant serum levels alongside gut microbiota (Yan et al. 2025), human breast milk (Bzikowska-Jura et al. 2024), and maternal soil ingestion during pregnancy (Lawluvi et al. 2026). These are listed as exposure and occurrence sources; the page does not yet draw conclusions about risk to these groups.

How is uranium measured in these food and water studies?

Several of the mapped studies measure uranium by ICP-MS, including analyses of baby purees (Henríquez--Hernández et al. 2023) and coffee beans (Albals et al. 2021). The FDA Total Diet Study documentation records uranium measurement limits of detection and QA/QC parameters by food category (FDA 2022), and a state--of-the-science review addresses uranium exposure biomarkers in blood, urine, and tissue (Martinez-Morata et al. 2023).

12 | What remains uncertain

The human toxicology evidence cited here rests on two cross-sectional analyses of one Finnish well-water cohort 2 8. They show associations with kidney tubule markers and, less firmly, bone turnover markers, not

disease. Mechanistic work in yeast, fish, rats and a zebrafish preprint points to cell-membrane, mitochondrial and olfactory-transport pathways, but the exposures and forms of uranium in those studies differ from natural uranium in drinking water 9 6 7 5.

Occurrence data cover groundwater in three countries and one produce survey near a uranium mine 2 3 4 10. None of these studies was designed to estimate typical population intake, and the guideline values quoted on this page come from study authors citing guideline editions that have changed over time 2 3 4.

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