Gallium

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Karen Pendergrass · Heavy Metal Index, Institute of Contaminant Standards

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Abstract

This page draws on 11 peer-reviewed studies. The complete citation list is at the bottom of the page.

1 | Overview

Gallium is a technology-critical element used mainly in integrated circuits and optoelectronic devices. Its ionic radius is close to those of aluminum, iron, magnesium, and manganese, so its movement in soil and plants is sometimes compared with those elements 1. No nutritional role is described in the cited literature. Gallium compounds have been studied as drugs because they compete with iron uptake and can inhibit the iron-dependent enzyme ribonucleotide reductase 2.

The other nine papers measure gallium rather than dose it as a drug. They report it in drinking groundwater 3, honey 4, urban garden vegetables 5, human plasma and serum 6 7 8, mining-affected water 9, mining-area soil 10, and river sediment 11. Across those measurements gallium is common in soil, sediment, and rural Chinese groundwater, usually at or below quantification in the foods tested, and present at low or undetectable levels in the blood samples.

2 | Toxicology

The cited evidence does not establish gallium toxicity in people at the concentrations measured in water, food, or blood. A national groundwater assessment could not obtain a reference dose for gallium, or for rubidium, thallium, or thorium, and left those four metals out of its noncancer risk totals 3.

Laboratory data concern a drug, not dietary exposure. In cultured human cells, the organic complex tris(8--quinolinolato)gallium(III), known as KP46, killed four bone-cancer cell lines at low micromolar concentrations and was less toxic to non-malignant lung fibroblasts, which showed no loss of viability up to 5 µM 2. The same paper, summarizing earlier work, states that simple gallium salts (gallium nitrate and gallium chloride) were tested clinically but that unfavorable pharmacokinetic and toxicological properties prevented routine use, and that KP46 has a strong affinity for bone 2. Those clinical statements are background, not new findings.

Three clinical studies report associations, not effects. Serum gallium was slightly higher in patients with renal cell carcinoma than in patients with benign kidney tumors; healthy controls matched the benign-tumor mean 7. Serum gallium also correlated weakly with estimated glomerular filtration rate in that study (r = 0.212, P = 0.034) 7. In a larger chronic kidney disease study, the median was 0 µg/L in both patients and the comparison group, with the comparison group's upper quartile at 0.02 µg/L 8. Plasma gallium did not differ by cognitive status in a small Taiwanese sample 6.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
2, Vienna (laboratory)	Human osteosarcoma cell lines, 72 h MTT assay	KP46 (organic gallium complex)	IC50 1.204 to 3.830 µM (mean of three experiments)	4 cell lines	Drug-level cell toxicity; not an exposure benchmark
2, Vienna (laboratory)	Non-malignant human lung fibroblasts, 72 h MTT assay	KP46	IC50 9.01 µM; no viability loss up to 5 µM	1 culture	Single comparison cell type
7, Mianyang, China, March 2021 to June 2022	Serum, kidney tumor case-control, ICP-MS	Total gallium	Mean 1.13 ± 0.16 µg/L (renal cell carcinoma), 1.04 ± 0.18 µg/L (benign tumors), 1.04 ± 0.18 µg/L (healthy controls); F = 4.453, P = 0.013	57, 43, and 50	Association only; small difference
6, Taiwan	Plasma, control vs amnestic mild cognitive impairment vs Alzheimer's disease	Total gallium	Median (1st, 3rd quartile) 0.071 (0.047, 0.095), 0.059 (0.024, 0.071), and 0.036 (0.035, 0.036) µg/L; age-adjusted P = 0.173 and 0.248 vs control	9, 23, and 8	No significant group difference; Alzheimer's group is small
8, Shenyang, China, November 2021 to August 2022	Serum, chronic kidney disease vs health-exam comparison group	Total gallium	Median (IQR) 0 (0, 0) µg/L in patients and 0 (0, 0.02) µg/L in the comparison group; P < 0.001	443 and 100	Both medians sit at the detection floor; values below the detection limit were replaced with half the limit in the analysis

3 | Typical exposure routes

Drinking water is the best quantified route in the cited evidence. In 166 groundwater samples from wells used for drinking in 28 Chinese provinces, municipalities, and autonomous regions, collected in July of 2016, February

of 2017, and July of 2017, gallium was reported as a median to maximum of 8.5 to 89 µg/L, with a detection frequency above 90 percent 3. Some of those provinces were not sampled. The paper does not give a mean or a lower percentile in the main text.

Mining can release gallium to water. Around artisanal gold mining in Marmato, Colombia, the authors state that gallium was detectable and that concentrations were elevated in mining-affected waters, and they attribute it to substitution in the zinc sulfide mineral sphalerite 9. The main text prints no gallium concentration.

Gallium is abundant in soils and sediments relative to plant tissue. Soils at a selenium mine in Enshi, China, held 27.76 ± 1.81 mg/kg in the control, 20.1 ± 2.24 mg/kg at the lower selenium level, and 10.24 ± 3.59 mg/kg at the higher selenium level 10. Bottom sediments of the Biała Przemsza River in a Polish zinc and lead mining district averaged 11.8 mg/kg, with a maximum of 25.6 mg/kg 11. Most of that sediment gallium was in the residual mineral fraction. The largest share in the more mobile amorphous iron and aluminum hydroxide fraction was 7 percent 11.

Human blood is a measured internal marker, not an intake. The serum and plasma values above are single blood draws. They do not identify which food or water supplied the gallium.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
3, rural China, 2016 to 2017	Groundwater used for drinking, ICP-MS	Total gallium	Median to maximum 8.5 to 89 µg/L; detection frequency above 90 percent	166 wells	Main text gives median and maximum only; full distribution is in a supplement
11, Biała Przemsza River, Poland	Bottom sediment, ICP-MS	Total gallium	Average 11.8 mg/kg (11,800 µg/kg); maximum 25.6 mg/kg at site BP3	several sites and seasons	Mining-affected river; mostly residual, so not readily mobile
10, Enshi, China	Mining-area soil, ICP-MS	Total gallium	27.76 ± 1.81, 20.1 ± 2.24, and 10.24 ± 3.59 mg/kg (control, low selenium, high selenium)	30 samples collected for the microbial work; chemistry group size not stated	Soil, not food; gallium was lower where selenium was higher

4 | Food sources

Few foods in the cited evidence contain measurable gallium. Gallium was analyzed in 61 honey samples from eight regions of Romania and was not detected in any of them 4. The results column is labeled µg/kg. The footnote prints a quantification limit of 0.04 µ/L for the gallium isotope measured, so the non-detect cannot be restated as a honey concentration in µg/kg without a dilution factor the paper does not apply.

In Vienna urban gardens, gallium in tomato fruit parts (skin, pulp, and seeds) was below the quantification limit, together with beryllium, iron, cobalt, nickel, silver, thallium, lead, and uranium 5. Numeric gallium mass fractions for other garden tissues are in a supplement that is not restated here.

Wild plants on uncontaminated soil in St. Petersburg took up only a small share of soil gallium. At one site, rhizosphere soil held 6.55 ± 0.33 mg/kg under couch grass and 7.32 ± 0.73 mg/kg under plantain. Roots held 1.52 ± 0.45 and 0.46 ± 0.14 mg/kg, and leaves held 0.058 ± 0.010 and 0.14 ± 0.05 mg/kg 1. Those figures are mg/kg after the plants were washed and air dried to constant weight. The same paper cites other work for a plant range of 0.001 to 0.30 mg/kg on uncontaminated soils, mostly in crops such as rice and wheat, and a soil range of 3 to 300 mg/kg 1. Those ranges are background citations, not new measurements, and the plants in the study are weeds, not foods.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
4, Romania	Honey, eight regions, ICP-MS	Total gallium	Not detected in any sample. Footnote quantification limit 0.04 µ/L; table unit µg/kg	61	One food, one country; the two units are not reconciled in the paper
5, Vienna	Tomato fruit skin, pulp, and seeds	Total gallium	Below the quantification limit	see paper	Numeric tissue values are in the supplement
1, St. Petersburg, site 1	Wild plant leaves, air dried to constant weight	Total gallium	0.058 ± 0.010 mg/kg couch grass (58 ± 10 µg/kg); 0.14 ± 0.05 mg/kg plantain (140 ± 50 µg/kg)	3 to 6 plants per sampling	Weeds, not food crops

5 | Regulatory limits

The cited evidence does not state any food, drinking water, or supplement limit for gallium, and it does not state a tolerable intake. The groundwater risk assessment explicitly found no reference dose for gallium in the databases it searched 3.

6 | Testing

ICP-MS is the method used for gallium in every concentration study cited here: groundwater, honey, garden vegetables, wild plants, serum, plasma, mining water, mining soil, and river sediment 3 4 5 1 7 6 8 9 10 11. The drug study measured cell viability, not gallium content 2.

Quality checks differ. The plant study compared results with two certified plant reference materials and found differences under 10 percent 1. In that study, gallium in rhizosphere soil changed by about 20 percent during a day, and gallium in roots changed by more than two times, so the hour of sampling can move the result 1. In the Marmato water study, indium measured alongside gallium may have been an artifact because indium was the

ICP-MS internal standard; the authors do not say that about gallium 9. The kidney tumor study used germanium as the internal standard for gallium 7.

7 | Microbiome effects

The cited evidence does not establish any effect of gallium on the human gut microbiome. In selenium-impacted mining soils, gallium was one of several elements positively correlated with bacterial community composition, and a random forest model placed it among the top predictors of bacterial diversity 10. That is a soil correlation. Gallium moved with many other elements, so the analysis does not show that gallium itself changed the community.

8 | Vulnerable populations

The cited evidence does not identify a group with a demonstrated health risk from gallium. Rural households using untreated groundwater had the highest measured water concentrations in this set 3, and communities near the Marmato workings are the group the mining study describes as exposed 9. Neither paper links those concentrations to a health outcome. The clinical studies enroll people with kidney tumors, chronic kidney disease, or cognitive impairment. They do not show that gallium caused those conditions 7 8 6.

9 | Mitigation

Washing lettuce significantly reduced gallium on the leaves, along with beryllium, aluminum, vanadium, nickel, and thallium, which is consistent with a surface-bound fraction 5. The paper does not give the size of that reduction in the main text. The cited evidence does not describe a water treatment or a soil treatment that removes gallium.

10 | Open questions

- No regulatory limit, guidance value, or reference dose for gallium is cited.
- Dietary intake has not been estimated. The foods with a gallium result are honey, all below quantification, and tomato fruit, also below quantification.
- Toxicity at the measured water, food, and blood levels is not established. The only dose data are drug concentrations in cells.
- The Marmato paper describes gallium in mining water as elevated and does not print a concentration.
- Garden vegetable concentrations other than the tomato non-detect are in a supplement and are not on this page.
- Whether soil gallium changes microbes, or only travels with other elements, is not resolved.

11 | What remains uncertain

Each matrix on this page rests on one study. The groundwater median of 8.5 µg/L and the maximum of 89 µg/L come from rural China in 2016 and 2017 and may not describe other supplies. The honey non-detect is one country and one food, and the paper's quantification limit is not in the same unit as the results column.

Without a toxicity benchmark, these concentrations cannot be read as a risk or as a clearance. The renal cell carcinoma mean is 1.13 µg/L and the other two group means are 1.04 µg/L, from one hospital, and the chronic

kidney disease medians are both zero. Cell-line toxicity at micromolar drug concentrations does not translate into a level of everyday exposure.

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DATA AVAILABILITY

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