Selenium

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HEAVY METAL INDEX · REFERENCE November 2026

CITE AS

Pendergrass, K. (2026). Selenium. Heavy Metal Index. https://heavymetalindex.com/metals/selenium

CORRESPONDENCE

Corrections are logged publicly on the article page, each with its date, the affected value, and the source that resolved it.

KEYWORDS

heavy metals, food safety, dietary exposure

PUBLICATION HISTORY

This revision 2026-11-03.

Abstract

This page draws on 20 peer-reviewed studies and 4 other cited sources. The complete citation list is at the bottom of the page.

1 | Overview

Selenium is an essential trace element that is also toxic in excess. In the body it is built into selenoproteins as selenocysteine, and surplus selenium is methylated for excretion 1. One review notes that in experimental animals the span between deficient and excessive doses is only about tenfold, roughly 0.1 to 1.0 µg/g of diet 1.

The amount of selenium people eat depends mainly on the soils that produce their food. Reviews estimate that inadequate intake affects hundreds of millions of people, citing figures of 800 million and of at least a billion 2 3. Food balance sheet modeling put more than 80% of the Malawi population, and 22% of Africans overall, at risk of inadequate intake 4. At the other extreme, people eating locally grown food on seleniferous soils in Punjab, India, had mean intakes above 600 µg per day in men 5.

This page summarizes the cited studies on intake, food concentrations, status biomarkers and excess exposure. Nutrient adequacy and contamination are both relevant for selenium, and the sections below keep them distinct.

2 | Toxicology

Excess intake

The clearest excess-exposure evidence cited here comes from a seleniferous area of Punjab. Mean measured intake was 632 µg per day in men and 475 µg per day in women, compared with 65 and 52 µg per day in a nearby non-seleniferous area; 60% of men exceeded 600 µg per day 5. Hair and fingernail selenium were tens of times higher, and residents reported hair loss, nail blackening and nail loss 5. Those symptom counts come without a comparison group, so they show signs consistent with selenosis rather than a dose-response threshold.

A review describes chronic selenosis in Enshi County, China, where coal-contaminated soil held up to 8 mg/kg selenium and residents consumed up to 7 mg per day, with nail thickening and cracking, hair loss and skin lesions 3. A 1978 government survey cited a then-current estimate that toxicity follows prolonged intake of 2400 to 3000 µg per day 6. These are secondary statements and are not reassessed here.

Absorption, retention and excretion

In four New Zealand women, food selenium absorption averaged 0.79 of intake (range 0.76 to 0.83), and selenium balance was close to zero at an intake of 24.2 µg per day 7. Whole-body selenium estimated from selenomethionine tracer data (means of 5.2 to 6.9 mg) was higher than estimates from selenite data (means of 2.6 to 3.5 mg), showing that chemical form changes apparent retention 7. An earlier balance study found urinary selenium equal to roughly half of intake 8.

Selenite, selenate, selenomethionine and selenocysteine are all converted to a common intermediate, selenide; selenomethionine first passes through selenocysteine 1. The main urinary metabolite is a selenosugar, and trimethylselenonium, once proposed as a marker of excessive dose, is described as contested 1.

Form-dependent toxicity outside human diets

Form also changed toxicity in non-dietary studies. In one mouse neuroblastoma cell line, the IC50 of sodium selenite was 14.01 µg/mL, against 127.28 µg/mL for plant-made selenium nanoparticles 9. Honey bees fed selenate became less responsive to sugar and died more often under chronic dosing, while selenomethionine raised mortality only at the highest dose 10. Neither study supports human dose limits.

Low status

Low selenium status was the more common finding in the cited human studies. Older adults with Alzheimer's disease in Sao Paulo had lower plasma, erythrocyte and nail selenium than controls, but this case-control design cannot show cause and effect 11. The New Zealand total diet survey and the Malawi maize survey describe severe deficiency as associated with Keshan disease, a heart condition, and Kashin-Beck disease, a bone and joint condition 12 13.

3 | Typical exposure routes

Diet is the main route described in the cited studies. Measured or modeled intakes vary more than a hundredfold across populations.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
4 Malawi, acid soils	Duplicate diets, adult women	Total selenium	Median 6.5 µg/day (range 1.1 to 62.3)	56	Measured; one area
4 Malawi, calcareous soils	Duplicate diets, adult women	Total selenium	Median 55.3 µg/day (range 5.8 to 192)	58	Eightfold higher than acid-soil villages

5 Malawi, national	Maize grain survey, modeled intake from maize	Total selenium	Median 6.7 µg/day from maize	88 sites	Maize only; industry-funded
6 New Zealand	Total diet survey, 2003-4	Total selenium	Mean 49 µg/day (women 25+) to 71 µg/day (men 19 to 24)	968 samples	Average consumers only
7 United Kingdom	Total diet study, 1974	Total selenium	About 60 µg/day	6 centers	Historical
8 Punjab, seleniferous area	All foods eaten, analyzed	Total selenium	Mean 632 µg/day (men), 475 µg/day (women)	40 + 40	Excess exposure
8 Punjab, non-seleniferous area	All foods eaten, analyzed	Total selenium	Mean 65 µg/day (men), 52 µg/day (women)	40 + 40	Comparison area
9 New Zealand	Balance study, usual diet	Total selenium	Mean 24.2 µg/day	4	Very small
11 Sao Paulo, Brazil	3-day food record, older adults	Total selenium	Mean 40.99 (patients) and 48.91 (controls) µg/day	28 + 29	Food composition data

Crop selenium, and so dietary selenium, depends on soil supply. Grain from high-pH Eutric Vertisol soils in Malawi carried up to 10 times more selenium than grain from other soils 13. Atmospheric inputs are a further source of selenium to farm soils, and modeling projects that these inputs to Northern Hemisphere farmland will fall by 55 to 80% by the end of this century as air pollution controls and cleaner energy cut emissions 14.

4 | Food sources

Seafood, organ meats, eggs and some cereal products carry the most selenium; milk, fats, fruit and most vegetables carry little 6 12. In the New Zealand total diet survey, seafood, chicken, eggs, breads and grain products supplied most dietary selenium 12. In the United Kingdom in 1974, cereals supplied about half and meat and fish about 40% 6.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
7 London, United Kingdom	Brazil nuts, raw	Total selenium	2.3 to 53 mg/kg, as sold	8	Wide sample-to-sample range
7 London, United Kingdom	Pig kidney, raw	Total selenium	2.16 to 2.81 mg/kg, as sold	3	Single-sample values

7 London, United Kingdom	Bread-making and wholemeal flour versus plain flour	Total selenium	0.42 and 0.53 versus 0.04 mg/kg	1 each	Authors link high values to imported wheat
6 New Zealand	Mussels, table-ready	Total selenium	Mean 0.565 mg/kg (0.449 to 0.639), as eaten	8	Highest food in survey
6 New Zealand	Fresh grilled fish	Total selenium	Mean 0.492 mg/kg, as eaten	8	Composites
6 New Zealand	Boiled egg; fried chicken	Total selenium	Mean 0.269 and 0.199 mg/kg, as eaten	8 each	Authors link egg values partly to feed supplements
6 New Zealand	White bread; whole milk	Total selenium	Mean 0.035 and 0.007 mg/kg, as eaten	8 each	Low-selenium soils
5 Malawi	Maize grain, farm fields	Total selenium	Median 0.019 mg/kg dry weight (0.005 to 0.533)	88	Soil pH drives the high values
16 Brazil, China, India, Pakistan, Thailand	Brown rice, untreated trial plots	Total selenium	Site means 3 to 404 µg/kg dry weight (mean 95)	21 sites	Trial plots, not retail rice
15 Burkina Faso	Wild freshwater fish muscle	Total selenium	Reservoir means 147 to 264 µg/kg wet weight	22 to 49 per reservoir	No biomagnification
17 Shaanxi, China	Winter wheat grain, no added selenium	Total selenium	25 µg/kg dry weight	not stated	Low-selenium loess soil

Relevant ingredient pages: bivalve molluscs, fish, freshwater fish, organ meats, eggs, chicken, wheat flour, wheat, corn, rice, breast milk.

In the Burkina Faso reservoirs, selenium did not increase up the food chain, and every fish had more selenium than mercury on a molar basis, although the ratio of selenium to methylmercury fell in top predators 15.

Fertilizer practice changes crop selenium sharply. On Chinese loess soil, soil-applied selenate raised cabbage leaf selenium by 76.8 µg/kg and wheat grain by 17.4 µg/kg per gram of selenium applied per hectare, while selenite was much less effective 16. In a Polish field trial, selenate-fertilized carrots would supply 500 to 650% of the adult recommended allowance in a 100 g portion 17. A foliar spray containing sodium selenate raised brown rice selenium about fourfold, from a mean of 95 to 380 µg/kg 18. Plants take up selenate through sulfate transporters, so sulfur supply affects selenium uptake 2 14. Laboratory-grown Chlorella algae reached 857 µg/g dry weight selenium when cultured with selenite, mostly as organic forms 19.

5 | Regulatory limits

The cited evidence does not establish current regulatory limits for selenium in food, and no selenium regulation is among the cited sources. The values below are reference intakes and upper levels as quoted by the cited studies; they have not been checked against the issuing instruments and some are historical.

VALUE AS CITED	POPULATION	CITED IN
Recommended daily intake 70 µg/day (men), 60 µg/day (women); upper level 400 µg/day (adults) down to 60 µg/day (infants)	Australia and New Zealand reference values	6
Estimated average requirement 45 µg/day (over 10 years), 23 µg/day (under 10), 49 µg/day (pregnancy), 59 µg/day (lactation)	US values used for Africa risk estimates	4
Upper safe limits 400 µg/day (WHO) and 300 µg/day (EU); US reference dose 350 µg/day for a 70 kg adult	Adults, as reported in 2003	2
Recommended allowance 55 µg/day (adults), 60 to 70 µg/day (pregnancy and lactation)	Used to judge biofortified carrot	18

6 | Testing

The cited studies used several analytical approaches for total selenium:

- ICP-MS for foods, grain, duplicate diets, plasma and urine 12 13 4 18.
- ICP-OES for crops in fertilizer trials 17 20.
- Hydride generation atomic absorption spectrometry for foods, blood fractions, hair, nails and urine, and electrothermal atomic absorption for serum 5 21 22.
- Hydride generation atomic fluorescence for fish and invertebrates 15.
- Fluorimetry with diaminonaphthalene in older studies 6 8.

Quality control matters at the low concentrations typical of foods. In the New Zealand survey, recovery of selenium from a bovine muscle reference material fell as low as 69% 12. The plasma detection limit by ICP-MS was 0.055 µg/L in the Malawi study 4. Total diet surveys report foods on an as-eaten basis, while crop studies report dry weight, so values are not directly comparable 12 18. See also total diet study methodology.

Speciation was rarely measured. One trial measured selenomethionine in carrot by capillary electrophoresis and found no free selenate or selenite 17. Another estimated organic selenium in algae by difference 19. A review describes metabolite identification by speciation methods coupled to ICP-MS 1.

7 | Microbiome effects

The cited evidence does not establish effects of dietary selenium on the human gut microbiome. Two cited studies involve microbes in other settings. Selenate at 25 to 50 µg/L raised methane output by 30 to 35% in laboratory food-waste digesters 23. Selenium nanoparticles combined with lysozyme inhibited Staphylococcus aureus and Escherichia coli in culture 24. Neither result can be applied to the gut.

8 | Vulnerable populations

People on low-selenium soils who rely on a narrow range of locally grown staples are the clearest at-risk group for low intake. In Malawi, plasma selenium among women on acid soils was a median of 53.7 µg/L, less than half that of women near calcareous soils (117 µg/L) 4. New Zealand women aged 25 and over had a mean intake 18% below their recommended intake 12.

Older adults in care may have lower status. Institutionalized older adults in Southampton had mean plasma selenium of 0.81 µmol/L, against 1.03 µmol/L in healthy peers and 1.20 µmol/L in adults under 65 21. The authors attribute this to illness and reduced food intake rather than age itself.

Infants can have low intakes. Breast milk in the 1974 UK survey contained 0.01 to 0.02 mg/kg selenium, and the authors estimated infant intake could be little more than 5 µg per day unless certain cereals were eaten 6. In New Zealand the infant mean intake was 16 µg per day 12.

In France, women had slightly lower serum selenium than men, smokers had lower values, and obese women had lower values than other women 22.

For excess intake, residents of seleniferous areas who eat locally grown food are the group at risk; in Punjab, men exceeded 600 µg per day far more often than women (60% versus 7.5%) 5.

9 | Mitigation

The cited evidence does not establish processing, cooking or remediation methods that reduce selenium in food. For seleniferous areas, the Punjab study recommends public education to avoid excess intake 5. For fertilizer programs that add selenium to crops, the choice of selenate or selenite and the application rate determine whether crops reach or overshoot intake targets 17 16.

10 | Open questions

- No regulation or authoritative upper-level assessment is among the cited sources; the limits shown are second-hand.
- No cited study measures selenium in retail products by brand, in supplements, or in drinking water as a separate route.
- Effects of dietary selenium on the gut microbiome are not addressed by the cited evidence.
- Processing, cooking and remediation effects on food selenium are not established.
- Speciation in common foods (selenomethionine versus inorganic forms) is measured only in one carrot trial.
- Most intake data are from single regions, small samples, or decades old (United Kingdom 1974, New Zealand 1960s and 1970s).
- The doses at which selenosis signs appear are not established by the cited human data, which lack dose-response analysis.

- Several soil and crop studies have biofortification aims and some industry funding, and none measures market foods.

11 | What remains uncertain

The cited human evidence is mostly about low intake and status, from New Zealand, Malawi, Brazil, the United Kingdom and France. Only one study measures excess dietary intake directly, and its symptom data lack a comparison group, so the boundary between safe and harmful intakes rests on values quoted from other assessments rather than on the cited studies.

Food concentration data come mainly from two total diet surveys, one of them from 1974, and from crop trials on experimental plots. Because soil drives selenium in plant foods so strongly, these values may not transfer to other regions or to foods sold today.

Mechanistic and form-specific findings (absorption, retention, cell and insect toxicity) come from very small human studies, a single cell line, or non-human organisms, and cannot be scaled to human dietary limits.

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STATUS AND LICENCE

Editorially reviewed in-house; no external peer review has been completed on this reference. Published as an institutional technical report with its review state tracked on the article page. Released under CC BY 4.0.

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PUBLICATION HISTORY

This revision 2026-11-03. The full dated record is maintained at https://heavymetalindex.com/metals/selenium.