Iron

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Abstract

Essential to heme proteins, iron can also cause toxicity through acute poisoning or chronic overload. A developing source-context profile.

This page draws on 17 peer-reviewed studies and 1 other cited source. The complete citation list is at the bottom of the page.

1 | Overview

Iron is essential for hemoglobin, myoglobin, heme enzymes, and mitochondrial enzymes 1. That toxicology chapter attaches iron to the wiki as both an essential nutrient and a toxicity concern through acute poisoning and chronic iron overload 1.

Most iron reaches people through food, and in parts of rural Bangladesh also through drinking water drawn from tubewells 2. Dietary iron comes in two forms. Haem iron, carried by meat, poultry and fish, is absorbed more efficiently than non-haem iron, which is the form in plant foods, fortificants and supplements 3. In national survey data cited for India, about 70% of the iron consumed comes from cereals and only about 1% from heme sources 4.

The cited evidence frames iron as a two-sided exposure problem. Low iron status is common in women of reproductive age, both in India 4 and in young Australian women 3. At the same time, modeling for Indian states shows that combining staple-food fortification with programmatic supplementation can push a large share of women above the tolerable upper level of 45 mg per day 4, and rodent studies link high dietary iron loads to oxidative stress and altered energy metabolism 5 6.

2 | Toxicology

The textbook framing on this page names two toxicity pathways, acute poisoning and chronic overload 1. The newer papers behind this page add animal evidence on the chronic side; none of them measures acute iron poisoning in people, and none provides a human dose-response.

Dietary iron loading in rodents

Rats fed a diet with 650 mg iron per kg, compared with 45 mg per kg, for two weeks before and during fractionated gamma irradiation (3 Gy in 8 fractions) had 33% higher plasma iron and 26% higher liver iron, an altered radiation response in serum catalase, glutathione peroxidase and total antioxidant capacity, and retinal and aortic gene-expression changes consistent with an interaction between iron loading and radiation 5. The methods text describes the diet doses per kilogram of body weight while the results describe them as dietary content, so the exact dose metric is ambiguous 5.

Mice fed chow supplemented with 25 g carbonyl iron per kg for 14 days, against a standard chow containing 180 mg iron per kg, showed higher circulating glucose, aspartic acid and hydroxybutyric acids, lower lactate and malate, stimulation of the liver urea cycle and increased markers of oxidative stress 6. The authors describe this dietary iron load as supra-physiological, and the groups were very small (3 control and 5 treated mice) 6.

Nasal route in mice

Intranasal ferric ammonium citrate at 200 mg/kg, given twice every other day, impaired olfactory discrimination in mice, raised olfactory bulb iron-56 by 59.66% by ICP-MS, and activated microglia and astrocytes, with selective vulnerability of dopaminergic and glutamatergic neurons and oligodendrocytes but no ferroptosis signature 7. Serum iron did not change and cerebrospinal fluid iron was undetectable, which the authors interpret as direct transport along the olfactory nerve 7. This is a pharmacological dose of a soluble salt, not a measured environmental air exposure.

Screening risk from drinking water

A drinking-water survey in Jashore, Bangladesh, applied hazard-quotient arithmetic with an oral reference dose of 0.7 mg/kg per day and found adult iron hazard quotients from 0.004 to 1.446 (median 0.161), above 1 at 7 of 85 wells, while all child quotients were below 1 (maximum 0.590) 2. These are modeled screening values built on assumed water intake and body weight, not observed health effects, and the authors note that bioavailability was not measured 2.

3 | Typical exposure routes

Diet

Diet is the main route in the cited human studies. Young women in New South Wales had an energy-adjusted mean intake of 12.7 mg iron per day, of which 2.0 mg was haem iron and 10.7 mg non-haem iron (n = 270) 3. In India, cereals supply most dietary iron 4. Fortified foods can raise intake: astronauts on the International Space Station are reported to consume 20 ± 6 mg iron per day, and as much as 47 mg per day, because many of their commercial foods are fortified 5.

Drinking water

In 85 working tubewells in Jashore district that had previously been marked safe for arsenic, filtered iron ranged from 0.02 to 6.2 mg/L, with a median of 0.69 mg/L and a mean of 1.4 mg/L, and about 73% of wells exceeded the Bangladesh drinking-water limit for iron 2. The survey covered one dry season only 2. See water.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
11 Jashore, Bangladesh	Tubewell drinking water, cross-sectional, January to March 2017	Total iron, filtered	Median 0.69 mg/L (IQR 0.27 to 2.47); mean 1.4 mg/L; range 0.02 to 6.2 mg/L	85 wells	Dry season only; colorimetric method with a stated range of 0.02 to 3.0 mg/L
11 Jashore, Bangladesh	Wells above 2.0 mg/L	Total iron, filtered	Mean 3.72 mg/L (2.10 to 6.20)	24 wells (28%)	Class boundaries taken from the water values the paper cites
15 New South Wales, Australia	Food frequency questionnaire, healthy women aged 18 to 35	Total, haem and non-haem iron	12.7 ± 2.6 mg/day total; 2.0 ± 0.9 haem; 10.7 ± 2.7 non-haem (energy-adjusted)	270	Intake estimate, not measured food iron; haem fractions from older Australian food data

Soil and cosmetic clay context

One Nilore, Islamabad soil characterization reported iron of 170 µg/g by bulk elemental analysis (Table 2) 8. The source does not state a wet/dry basis or replicated uncertainty. This is a local soil result; it does not measure food occurrence or crop transfer.

A cosmetics study reports elemental XRF results for red and white cosmetic clays bought in Durban 9. Measurements refer to dried and ground market material, with no dermal absorption or species-specific determination.

Nasal route

The only nasal-route evidence is the mouse study described under Toxicology 7. The cited evidence does not establish inhalation or occupational exposure levels in people.

4 | Food sources

Measured iron in foods and crops

Bananas are a low-iron food: market Cavendish bananas in Queretaro, Mexico, contained 0.33 ± 0.04 mg iron per 100 g raw and 0.57 ± 0.02 mg per 100 g after steaming, on a dry basis according to the table footnote 10. In crops grown for an Indian feeding trial, biofortified pearl millet and a high-iron red lentil carried roughly twice the iron of their conventional comparators, while biofortified wheat and orange sweet potato were modestly higher 11. Relevant ingredient pages: banana, non-rice grains, wheat flour, sweet potato, lentils, legumes.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
13 Queretaro, Mexico	Raw ripe Cavendish banana, market	Total iron	0.33 ± 0.04 mg/100 g, dry basis	Duplicate analyses	Single market purchase for an absorption study
13 Queretaro, Mexico	Steamed green banana (matooke style)	Total iron	0.57 ± 0.02 mg/100 g, dry basis	Duplicate analyses	Abstract prints 0.53 mg/100 g for the same food
14 India	Pearl millet, biofortified versus control	Total iron	77.6 ± 1.7 versus 39.1 ± 0.6 µg/g, basis not labeled	3 replicates of one lot each	Dried, ground samples; one lot per variety
14 India	Whole-grain wheat flour, biofortified versus control	Total iron	61.2 ± 8.1 versus 47.5 ± 0.3 µg/g, basis not labeled	3 replicates of one lot each	Biofortification target was zinc, not iron
14 India	Sweet potato, orange biofortified versus white control	Total iron	6.7 ± 0.1 versus 5.7 ± 0.3 µg/g, wet weight	3 replicates of one lot each	Dry matter 0.20 and 0.31 respectively
14 India	Dehulled red lentil versus pigeon pea	Total iron	62.1 ± 0.6 versus 30.2 ± 0.4 µg/g, basis not labeled	3 replicates of one lot each	Locally available pulses, not bred varieties

Absorption and bioavailability

How much food iron is absorbed depends strongly on form and matrix. Women absorbed 49.3 ± 21.3% of the iron in raw banana and 33.9 ± 16.2% from cooked banana, but because cooked banana supplied more iron, total absorbed iron was similar (0.77 versus 0.86 mg) 10. Stable-isotope studies of cereal-based Indian meals reported mean absorption from 2.7% to 17.5% depending on cereal and anemia status, with a weighted mean of 8.7% 4. In an in vitro digestion and Caco-2 cell assay, biofortified pearl millet and red lentil gave higher iron uptake than their controls, wheat varieties did not differ, and adding sweet potato or sweet potato plus pulse raised uptake beyond what iron concentration alone predicted 11. Haem iron intake was a stronger predictor of serum ferritin than non-haem iron intake in young Australian women; the authors note that haem iron, found in meat, poultry and fish, typically makes up 10% to 15% of dietary iron in an omnivorous diet but contributes 40% or more of the iron absorbed 3.

Vegetable, leaf and chocolate occurrence studies

Rahim measured lead, cadmium, iron and copper in dried edible broccoli and cauliflower heads grown under three irrigation regimes in Sulaymaniyah, Iraq 12. The tables preserve crop-specific differences: wastewater--irrigated broccoli had the largest listed values for the four metals, whereas cauliflower cadmium was greatest under alternating irrigation. The paired treatment summaries contribute source-native vegetable occurrence and irrigation-pathway evidence. The dried basis is not interchangeable with fresh vegetables. The experiment

is site- and season-specific and does not characterize all river water, all Iraqi produce or long-term dietary exposure.

Joseph and colleagues measured seven metals in kenaf, chili pepper, tomato and spinach plant parts, with associated soil and irrigation water from Gobbiya Dam in Nigeria 13. The paper separates edible leaves or fruits from roots and stems. Its concentration tables are preserved independently of several inconsistent safety comparisons and a soil-index calculation that uses water standards. The organ-resolved dry-weight values support local occurrence and irrigation-pathway analysis. Roots, stems and non-edible leaves are retained as pathway context rather than assigned to edible-product distributions. Broad leafy-vegetable and herb/spice ingredient routes retain kenaf and chili identity in the structured record without substituting a named cultivar.

Premna latifolia leaves collected in three Andhra Pradesh villages had different reported elemental concentrations 14. Village-specific values are preserved as local leafy-vegetable evidence; the paper supplies no replicate counts or uncertainty estimates. Supports geographic variation in six elements in a specific wild edible leaf. It does not establish nutritional adequacy, safety, or a regional market distribution. The source's c haracterization of aluminium as an essential nutrient is not adopted.

Two anonymous chocolate products from Bwari market contained measurable nickel, iron, copper, chromium and lead 15. Their reported sample concentrations are preserved independently of inconsistent dispersion, intake means and safety comparisons in the paper. Provides a small local occurrence observation with anonymous products. It cannot establish market prevalence, source attribution, or a no-risk conclusion. Total chromium is not chromium(VI).

Gergen and Harmanescu analyze metal contamination patterns across two historic Romanian mining areas and a reference area 16. Their PCA study reproduces vegetable concentrations and male hazard quotients from the earlier Harmanescu 2011 study; these remain linked secondary observations rather than additional independent samples. Supports legacy mining and tissue/region differences. Parsley root and leaf remain distinct, as do carrot root and leaf. The fresh-matter food table is retained with cohort linkage so that a reanalysis cannot inflate the evidence pool. Source THQ rankings are model results, not clinical outcomes.

Rice roots and iron plaque

Rice seedlings exposed to trivalent chromium retained chromium in roots and surface iron plaques 17. Synchrotron speciation distinguished ferrihydrite-bound from organic-associated chromium(III), with different proportions in root tips and mature zones; the study concerns an upstream uptake mechanism rather than grain contamination. Supports chromium uptake and iron-plaque pathway evidence. Hotspot spectral fractions are not bulk rice-grain species fractions and cannot substitute for a chromium(VI) food result. Release of plaque-bound chromium during dissolution qualifies any assumption of permanent sequestration.

5 | Regulatory limits

No paper behind this page states a maximum level for iron in a food. The reference values that do appear are quoted secondhand by the cited papers:

- Drinking water: a WHO aesthetic value of 0.3 mg/L and a Bangladesh standard of 0.3 to 1.0 mg/L for iron, plus a 2.0 mg/L cut-off derived by allocating 10% of a JECFA provisional maximum tolerable daily intake of 0.8 mg/kg body weight to drinking water (60 kg body weight, 2 L per day) 2.

- Oral reference dose: 0.7 mg/kg per day, attributed by the Jashore survey to a 2006 United States Environmental Protection Agency provisional value and used for its hazard quotients 2.
- Intake: a tolerable upper level of 45 mg per day for women of reproductive age, used to model excess-intake risk in India 4. The same analysis proposes an Estimated Average Requirement of 15 mg per day for nonpregnant, nonlactating Indian women, against an existing Indian recommendation of 21 mg per day 4.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
12 India, 35 states and territories	Modeled risk of intake above 45 mg/day, 10 mg/day fortification	Total dietary iron	0% to 1% of women by state	State intake distributions	Depends on assumed fortification delivery
12 India, 35 states and territories	Same, plus 14 mg/day supplementation (100 mg weekly)	Total dietary plus supplemental iron	0% to 54% of women by state (Rajasthan 54%)	State intake distributions	Household purchase data, not individual intake

6 | Testing

The cited studies use several measurement approaches, each answering a different question:

- Drinking water was analyzed for filtered total iron by the FerroVer colorimetric method, whose stated range of 0.02 to 3.0 mg/L sits below the highest reported values of up to 6.2 mg/L; dilution is not described 2.
- Banana iron was measured by atomic absorption spectrometry, and absorption by double stable-isotope labeling with red-cell enrichment read by high-resolution ICP-MS 10.
- Crop iron was measured by ICP-AES after acid digestion, and relative bioavailability by an in vitro digestion and Caco-2 cell ferritin assay, which is a screening proxy rather than human absorption 11.
- Tissue iron isotopes in mouse olfactory bulb were quantified by ICP-MS 7.
- Cosmetic clays were characterized by elemental XRF on dried, ground material 9.
- Iron status was assessed by serum ferritin corrected for inflammation markers, while haem and non-haem intakes were calculated from questionnaire data and older food composition values rather than measured 3.

No cited study measures haem and non-haem iron directly in foods.

7 | Microbiome effects

The cited evidence does not establish microbiome effects of iron. One crop study suggests, as a rationale citing other work, that improving the share of iron absorbed could limit excess unabsorbed iron reaching the gut microbiome, but it did not measure microbial outcomes 11.

8 | Vulnerable populations

- Women of reproductive age. In India, the median state risk of inadequate iron intake was 65% at the newly derived requirement, falling to 20% with fortification of one staple and to about 3% with added supplementation, while the risk of exceeding 45 mg per day rose to as much as 54% in some states 4. Among 270 young Australian women, 26.3% were iron deficient and 5.9% had iron deficiency anemia, and women with high dietary restraint reported lower energy intake 3.
- Children drinking high-iron well water. In Jashore, child iron hazard quotients were lower than adult values because of the assumed intake and body weight, but the combined iron and manganese hazard index exceeded 1 at three wells for children, and the authors call children the most vulnerable population 2.
- People with very high fortified-food intakes. Astronaut intakes reported at up to 47 mg per day motivate the rat work on iron loading and radiation 5.

The cited evidence does not address people with genetic iron overload, pregnant women or infants directly.

9 | Mitigation

Column washing of Bangalore-area industrial sludge removed substantially more metals with hydrochloric acid plus EDTA than with distilled water 18. This is a remediation experiment relevant to sludge contamination pathways, with no measurements in food or a demonstrated safe land-application endpoint. Supports laboratory washing and contaminant-transport comparisons. Metal-rich leachate still requires management; the study does not establish agricultural reuse or field-scale safety.

For drinking water, the Jashore authors recommend periodic tubewell testing and low-cost household treatment, but they did not test any treatment 2. On the intake side, the Indian analysis argues that fortification and supplementation should be calibrated together so that reducing deficiency does not create excess intake 4. Removal of iron from foods by processing is not established by the cited evidence; cooking bananas changed fractional absorption rather than removing iron 10.

10 | Open questions

- Human toxicity dose-response: no cited paper measures acute iron poisoning or chronic overload outcomes in people; the toxicology evidence here is from rodents.
- Regulatory limits: the cited papers quote water values and intake reference values secondhand; no primary regulatory document for iron is cited, and no food maximum level appears.
- Food occurrence: measured food values come from one banana purchase and one lot per crop variety; there is no market survey of iron in foods.
- Drinking water: seasonal variation and particulate iron in high-iron tubewells were not measured.
- Speciation: haem and non-haem iron contents of foods were estimated from food composition data rather than measured.
- Microbiome effects: the cited evidence does not establish any microbiome effect of dietary iron.
- Vulnerable populations: pregnant women, infants and people with inherited iron overload are not covered.
- Mitigation: no tested method for removing iron from drinking water or food is reported.
- Nasal and inhalation routes: only one pharmacological mouse study; human exposure levels are not established.

11 | Frequently asked questions

What does iron do in the body?

Iron is an essential nutrient. It is required for hemoglobin, myoglobin, heme enzymes, and mitochondrial enzymes, according to Ufelle & Barchowsky 2021.

Can iron be toxic even though it's an essential nutrient?

Yes. Ufelle & Barchowsky 2021 attaches iron to the wiki as both an essential nutrient and a toxicity concern. The two toxicity pathways it identifies are acute iron poisoning and chronic iron overload.

What are the main ways iron causes harm?

The page identifies two mechanisms of iron toxicity: acute poisoning and chronic iron overload, as described in Ufelle & Barchowsky 2021. The page does not yet detail dose levels, affected populations, or specific health outcomes for either pathway.

12 | What remains uncertain

The human evidence on this page is about getting enough iron, not about too much. The excess side rests on modeled exceedance of a 45 mg per day upper level in India, on screening hazard quotients for Bangladeshi well water that depend on an assumed reference dose and water intake, and on short, high-dose rodent experiments whose doses cannot be translated to human diets. None of these establishes a threshold at which dietary or drinking-water iron harms people.

The occurrence data are thin. The food values come from a single banana purchase and one lot of each Indian crop variety, and the moisture basis of the grain and pulse values is not labeled. The drinking-water survey is large for one district but covers a single dry season. The older vegetable, leaf and chocolate studies kept on this page were designed around other metals and are not summarized here as iron distributions.

Several reference values on this page are quoted secondhand from primary documents that are not themselves cited here, so their current status and exact wording should be checked against those documents before any threshold is relied on.

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