Spinach

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Abstract

Cadmium is the metal that decides most spinach questions. spinach takes cadmium up from soil and moves it into the leaf, and the large monitoring datasets agree that ordinary retail spinach carries tens to a few hundred micrograms per kilogram on a fresh-weight basis: a median of 40 µg/kg across 2,077 randomly sampled European submissions to WHO GEMS/Food, 125 µg/kg in submissions from the Americas and 200 µg/kg in US Total Diet Study composites from 2018 to 2020. EU monitoring from 2003 to 2007 summarised by EFSA gave a median of 50 µg/kg and a mean of 61.5 µg/kg, against 23.1 µg/kg for other leafy vegetables. Against the EU maximum of 0.20 mg/kg for spinach, 105 of 2,262 raw spinach results in GEMS/Food and 10 of 27 US market composites were above the limit.

1 | Spinach overview

Lead, arsenic and mercury are usually low in monitored retail spinach.[1,2,5] US composites had a lead median of 6.2 µg/kg and a total-arsenic median of 5.9 µg/kg, and mercury was detected in 3 of 27; European and Canary Islands supermarket spinach showed the same picture, with lead medians of 13-22 µg/kg and mercury mostly below detection.[1,2,5] spinach is, however, rich in aluminum, around 41,000 µg/kg in Canary Islands and Malaysian market samples.[5,8]

The highest values in the library come from fields irrigated with sewage or industrial wastewater and from sites near a battery factory or industrial zones, where spinach carried several milligrams of cadmium, lead or nickel per kilogram.[4,9,10] Many of those studies report dry weight or do not state the basis, so they cannot be ranked against fresh-weight market data, but within single studies the polluted fields were consistently higher than cleaner comparison fields.[4,6,11] For a buyer the supported priorities are the growing site and its irrigation water, then lot results for cadmium and lead on a fresh-weight basis; packaging form (frozen fresh or canned) does not reliably change cadmium.[1,3,4]

2 | Spinach and its preparations

This page covers spinach, Spinacia oleracea: raw leaves, cooked baby spinach, frozen and canned spinach and spinach purée used as an ingredient, each kept as its own material.[1,2,12] Several plants are also sold as spinach but are different species: amaranth (African, red or Chinese spinach), water spinach (Ipomoea aquatica) and Malabar or Indian spinach (Basella).[13,14,15] Results for those plants, including the GEMS/Food submissions filed under the spinach code whose local names show water spinach, Chinese spinach or a mustard-green dish, are not counted here.[1]

The basis of a result matters as much as the form. Fresh spinach is about 93% water, so a dry-weight concentration is roughly 14 times the fresh-weight value for the same leaves; the page never converts between the two, and results whose basis is not stated stay separate.[6] Some field studies from Nigeria and South Asia name the crop only as spinach; where a paper identifies the plant as an amaranth it is excluded, and the remaining reports are taken at their word.[14,16,17] Mixed baby foods, creamed spinach, spinach tortillas and snacks that contain spinach are outside this scope, because their results cannot be attributed to the leaf.[1,2,18]

3 | How contamination reaches spinach

Spinach takes cadmium up through its roots and moves it readily to the leaves, while lead binds strongly in soil and moves little into leaves, so leaf lead mostly reflects soil or dust on the surface.[6] Chloride in soil or irrigation water makes cadmium more mobile and available to the plant, and older leaves accumulate more cadmium than young leaves because uptake follows transpiration.[6]

Irrigation water and industrial pollution raise every metal.[4,24] In Gazipur, Bangladesh, spinach from a field irrigated with heavily polluted river water carried 1,020 µg/kg cadmium, 5,970 µg/kg lead and 31,900 µg/kg nickel dry weight, against 430, 1,160 and 5,480 µg/kg on a non-industrial research field.[4] In a greenhouse trial, irrigating with water containing 500 µg/L arsenic raised spinach leaf arsenic from 1.05 to 6.57 µg/g dry matter.[24] Near a battery factory in Henan, village spinach carried 5,040 µg/kg cadmium and 1,930 µg/kg lead, and sewage-irrigated spinach in Faisalabad 3,580 and 6,130 µg/kg (basis not stated in either).[9,10]

Fertilizer and manure choices change lead and arsenic more than cadmium.[25] In a Turkish open-field trial, chicken, sheep and cattle manure and vermicompost raised spinach lead from 110 to 500-750 µg/kg, while cadmium stayed between 400 and 530 µg/kg in every treatment and arsenic, nickel and chromium fell below the unfertilised control.[25] Spiking pot soil with 3 mg/kg cadmium raised spinach leaf cadmium from 0.01 to 3.29 mg/kg dry weight, showing how directly soil cadmium transfers to the leaf.[26]

4 | Lower measured levels by site, region and type

For cadmium, the clearest lower-contamination choice is a growing site away from polluted irrigation water and industry, because that is the only difference measured within the same studies.[4,11] A non-industrial field in Gazipur gave 430 µg/kg dry weight against 1,020 µg/kg beside a polluted river, and a walled garden in Dehradun watered from a tube well and rain gave 260 µg/kg against 470 µg/kg in market spinach grown with mixed and partly wastewater irrigation.[4,11] Across monitoring datasets, the lowest observed retail cadmium was in Europe and the Canary Islands (GEMS/Food European median 40 µg/kg, Gran Canaria 21.5 µg/kg, a single Malaysian wholesale lot below 4 µg/kg), with the Americas (125 µg/kg) and US composites (200 µg/kg) higher.[1,2,5,8] These are purchase markets, not growing origins, and the periods differ, so they are tentative regional patterns rather than a supported country ranking.[1,2]

A 2024 review of US data supports part of that pattern: spinach sampled in the 1980s, mostly from lower-cadmium soils, would all have met a 0.20 mg/kg limit, while 40-50% of recent California and Arizona samples would not.[6] Within GEMS/Food, domestic and imported spinach had the same cadmium median (50 and 49 µg/kg), so the domestic-or-imported label alone does not identify lower-cadmium supply.[1] The review also reports that baby spinach had lower cadmium than the later bunching crop in a New Zealand field study; the library holds that comparison only as reported in the review, and GEMS/Food holds a single baby-spinach result, a lead non-detect below 5 µg/kg.[1,6]

For lead, nickel and chromium the same site contrast holds, and the size of the gap is larger than for cadmium.[4,11] Lead fell from 5,970 to 1,160 µg/kg and nickel from 31,900 to 5,480 µg/kg between the polluted and non-industrial Gazipur fields, and lead from 2,740 to 1,260 µg/kg and chromium from 2,710 to 1,090 µg/kg between Dehradun market spinach and the walled garden.[4,11] In retail data lead was lowest, apart from one Malaysian lot below 4 µg/kg, in US composites (median 6.2 µg/kg) and Americas submissions (10 µg/kg), with Europe at 14-22 µg/kg; total arsenic was low everywhere it was measured (US 5.9, Gran Canaria 8 and Western Pacific 7.45 µg/kg).[1,2,5] No study in the library compares field-grown with greenhouse or hydroponic spinach for any metal, so no growing-system preference can be stated; organic spinach appears in only two GEMS/Food cadmium results, too few to compare.[1]

Retail spinach was low in both: lead medians of 6.2 µg/kg in US composites, 10 µg/kg in Americas submissions and 12.8 µg/kg in Gran Canaria, and total arsenic 5.9-8 µg/kg.[1,2,5] Inorganic arsenic averaged 5 µg/kg in Hong Kong spinach, and five of seven European GEMS/Food results were below a 6 µg/kg reporting limit.[1,27] The highest lead values came from wastewater-irrigated and industrial sites in Bangladesh, India, Pakistan and China.[4,9,10,28]

Not in the monitoring data.[1] European frozen spinach had a higher cadmium median (71 µg/kg) than raw spinach (40 µg/kg), and the single canned European result was 130 µg/kg; these are different samples, so the comparison does not show what processing does to a given lot.[1]

5 | Freezing, cooking, washing and purée

Freezing, cooking and canning did not lower cadmium in the monitoring data.[1] frozen in randomly sampled european gems/food submissions spinach had a cadmium median of 71 µg/kg and cooked spinach 66 µg/kg, against 40 µg/kg for raw; in the Americas cooked spinach (116 µg/kg) was close to raw (125 µg/kg).[1] These are different samples, not paired before-and-after measurements, so the differences cannot be read as an effect of processing; cooking does drive off water, which concentrates cadmium per kilogram of cooked leaf.[1,6]

Washing removes soil and dust but little of the cadmium inside the leaf.[6] The 2024 review estimates that leaf washing lowers spinach cadmium by only about 8-15%, compared with 20-80% for zinc amendment of soil.[6] Boiling in clean water removed 3-31% of the arsenic from greenhouse spinach, but boiling market spinach in water containing 1,000 µg/L arsenic raised it from 0.01 to 0.75 µg/g fresh mass, so the cooking water itself can add arsenic.[24]

Spinach purée and canned spinach behave as concentrated or prepared forms.[1,12] Cadmium in spinach purée tested by a US baby-food manufacturer before use (143 µg/kg) was in the same range as its fresh spinach lots (101-142 µg/kg), and canned spinach in the Americas had a lead median of 8.5 µg/kg.[1,12] The library holds no paired measurement of a spinach purée or canned product and the leaves that went into it.

6 | Controls for spinach

Controls for spinach act mainly where it grows: choosing the field, the irrigation water and the soil inputs.[4,6,24] In pot trials, zinc added to cadmium-spiked soil at 300 mg/kg lowered spinach leaf cadmium from 3.29 to 1.96 mg/kg dry weight, while 30 mg/kg had no effect, and acidified biochar at 1.2% lowered shoot cadmium by 33-59%.[26,29] The 2024 review rates lime with zinc and limiting chloride inputs as the most effective field measures, at about 60% and 40% cadmium reduction, and cultivar choice at 0-50%.[6]

For lead and arsenic the controls are site and water rather than amendments.[25,24] Avoiding lead-bearing manures matters, because manures raised spinach lead four- to sevenfold in an open-field trial, and arsenic-free irrigation and cooking water are the controls the Burkina Faso trials support for arsenic.[25,24] After harvest, lot testing against the spinach limits detects high lots but does not lower contamination.[3]

7 | Trade-offs and failure modes

Measures that lower one metal can raise another.[25] The manures that lowered arsenic, nickel and chromium in Turkish spinach raised its lead, and vermicompost, the only treatment that lowered cadmium slightly (400 against 430 µg/kg), raised lead to 540 µg/kg.[25] Zinc at the effective rate also cut spinach shoot growth by about 17% in the pot trial.[26]

Pot-trial effects do not transfer directly to commercial fields.[26,29,30] The zinc, biochar and chromium-stress trials used spiked or contaminated soils in pots, and several read their spinach results only from charts, so their percentage effects describe those conditions.[26,29,30,31] spinach also contains oxalate, which the 2024 review notes may bind cadmium in the leaf and affect how much is absorbed when eaten; that effect on exposure has not been measured.[6]

8 | Sampling and testing spinach

A spinach result is only comparable when the basis is stated. Many field studies report dry weight, which is about 14 times the fresh-weight value, and then compare it with fresh-weight limits, overstating exceedance; the EU limits apply to wet weight after washing and separating the edible part.[3,6] A useful report gives the form (raw, frozen baby, cooked or purée), fresh-weight basis, whether it was washed, the growing site and the quantification limit for each metal.[2,3]

Reporting limits must sit well below the decision level.[1,2] US composites reported lead down to 4 µg/kg and cadmium to 1 µg/kg, while several surveys print values below their own detection limits, and one Pakistani study reports mercury after open digestion at 200 °C, conditions that lose mercury; those rows are held.[2,10,19] Total arsenic is not inorganic arsenic, and inorganic mercury submitted to GEMS/Food is not total mercury; the page keeps each species separate.[1,27]

Some extreme values do not survive a check against their own papers. In a Dhaka market study every detected lead value was below the method's own detection limit, and in an Iranian field study the cadmium standard d eviation was eleven times the mean.[19,20] Other high values are real but come from wastewater-irrigated or industrial sites and from dry-weight measurements, which are about 14 times fresh-weight values.[4,6,9]

9 | Sourcing and supplier evidence

Spinach has its own cadmium limit in several markets.[3,32,33] The EU sets 0.20 mg/kg cadmium for spinach and similar leaves, double the 0.10 mg/kg for other leaf vegetables, 0.30 mg/kg lead for leaf vegetables and, from July 1, 2025, 0.50 mg/kg nickel for leafy vegetables, all on wet weight.[3,34] Korea sets 0.3 mg/kg lead and 0.2

mg/kg cadmium for spinach, China 0.3 mg/kg lead and 0.2 mg/kg cadmium for leafy vegetables, and Hong Kong 0.2 mg/kg cadmium for leafy vegetables; the Codex 0.3 mg/kg lead level for leafy vegetables in the edition held in the library excludes spinach.[32,35,33,36]

Cadmium is the result most likely to approach a limit.[1,2,7] In GEMS/Food, 105 of 2,262 raw, 48 of 773 frozen and 11 of 105 cooked spinach results were above 0.20 mg/kg cadmium, against 23 of 2,111 raw results above 0.30 mg/kg lead; EFSA counted 34 of 867 (3.9%) EU spinach samples above the cadmium limit.[1,7] Ask for lot cadmium and lead on a fresh-weight basis with the growing region and irrigation source, because most datasets identify only the market and the clearest high-contamination cases are site-specific.[1,4,6]

10 | Spinach in foods and dietary exposure

Spinach is a measurable contributor to cadmium and nickel intake for people who eat it often.[6,37] In a Danish average-diet estimate spinach supplied about 1.04 µg of nickel a day from a literature mean of 0.52 mg/kg, with the highest nickel load factor of the vegetables listed.[37] The 2024 review cites baby-food testing in which products containing leafy greens such as kale and spinach tended to contain more cadmium, and an FDA survey of baby foods found that 18 of 20 purées and mixtures above its cadmium 95th percentile listed tomato, spinach or carrot among their ingredients.[6,18]

Exposure depends on how much is eaten and in what form.[2,6] Raw spinach is mostly water, so a cooked portion that has lost water carries more cadmium per gram than the same leaves raw.[6] No source in the library measured metals in a finished spinach product together with the spinach that went into it, so finished-product concentrations cannot be inferred from the leaf values here.

11 | Evidence review and remaining questions

This assessment covers every source record in the library tagged to spinach or naming it, and every spinach row in WHO GEMS/Food, the FDA Total Diet Study and the other indexed datasets; each item has a recorded decision based on its content.[1,2] Studies of amaranth, water spinach and Malabar spinach, papers that print spinach values only in charts and pooled vegetable groups are recorded but not used as spinach results.[14,38,39]

Remaining gaps are specific. The Peruvian mining-region dataset with spinach results is held in an external repository not in the library, the New Zealand comparison of baby and bunching spinach is available only through a review, and no study compares field-grown with greenhouse or hydroponic spinach.[6,40] Inorganic arsenic was measured directly only in GEMS/Food submissions and the Hong Kong total diet study.[1,27]

References identify the sources used in these answers. The Sources index preserves additional discovery links; inclusion there does not mean a source has been reviewed for this assessment. Corrections, completed searches, new direct evidence and changes in requirements should reopen the relevant answer.

12 | Spinach FAQs

Cadmium is found in almost every spinach sample and is the one most often at levels that matter.[1,2] Lead, total and inorganic arsenic, mercury, nickel, chromium, aluminum, tin and uranium have also been measured; in monitored retail spinach lead and arsenic are usually low and mercury mostly below detection.[1,2,5]

Spinach roots take cadmium up from soil and the plant moves it into the leaves, more readily than lead; chloride in soil or water increases its uptake.[6] Spiking pot soil with 3 mg/kg cadmium raised leaf cadmium from 0.01 to 3.29 mg/kg dry weight.[26]

Yes, in several markets.[3,32] The EU maximum is 0.20 mg/kg wet weight for spinach and similar leaves, and Korea, China and Hong Kong set 0.2 mg/kg for spinach or leafy vegetables; lead limits are 0.3 mg/kg.[3,32,35,33] No US cadmium limit for spinach appears in the sources held; the 2024 US review evaluates US data against the EU value.[6]

In GEMS/Food, 105 of 2,262 raw spinach results (about 5%) were above 0.20 mg/kg, and EFSA counted 3.9% of EU samples above the limit.[1,7] US market composites from 2018 to 2020 exceeded 0.20 mg/kg in 10 of 27 cases.[2]

The supported answer is a site rather than a country: fields away from polluted irrigation water and industry.[4,11] Retail monitoring found lower medians in Europe (40 µg/kg) and Gran Canaria (21.5 µg/kg) than in the Americas (125 µg/kg) and US composites (200 µg/kg), but these record where spinach was bought, not where it grew.[1,2,5] A US review reports higher cadmium in recent California and Arizona spinach than in 1980s samples from lower-cadmium soils.[6]

Probably, but the library holds only indirect evidence.[6] A 2024 review explains that older leaves accumulate more cadmium and cites a New Zealand field study in which baby spinach had lower cadmium than the later bunching crop; the only direct baby-spinach result in the library is one lead non-detect.[1,6]

The library cannot say.[1] Only two organic spinach cadmium results are in GEMS/Food, and the one fertilizer trial found that organic manures raised spinach lead four- to sevenfold while leaving cadmium almost unchanged.[1,25]

Only the part on the surface.[6] Washing removes soil and dust, which carry most surface lead, but the 2024 review estimates only an 8-15% cadmium reduction, because cadmium is inside the leaf.[6]

Cooking does not destroy metals.[6,24] Boiling in clean water removed 3-31% of arsenic from spinach, but boiling in water with 1,000 µg/L arsenic raised spinach arsenic about 75-fold, and the water lost in cooking concentrates cadmium per gram.[6,24] Cooked spinach in monitoring data had cadmium medians similar to or above raw spinach.[1]

Not lower in cadmium.[1] European frozen spinach had a cadmium median of 71 µg/kg against 40 µg/kg for raw, and a lead median below 20 µg/kg, similar to raw; these are different samples, not the same lots before and after freezing.[1]

Most come from spinach grown on wastewater-irrigated or industrial sites, and many are on a dry-weight basis, about 14 times fresh-weight values.[4,6,9,10] Some extreme values fail checks against their own papers and are held on this page.[19,20]

Spinach is one of the cadmium sources identified for infant foods.[6,18] An FDA survey found that 18 of 20 purées and mixtures with the highest cadmium listed tomato, spinach or carrot, and spinach and purée tested by a manufacturer before use carried 101-143 µg/kg cadmium.[18,12] No authoritative serving guidance for spinach and metals is in the library.

A lot compared with other leaves.[5,8] Gran Canaria supermarket spinach had a median of 41,900 µg/kg and Malaysian market spinach averaged 41,400 µg/kg, and cooked spinach in Hong Kong 13,000 µg/kg, the highest of the leaves in the Gran Canaria survey.[5,8,13]

Mostly it is measured only as total arsenic, which was low in retail spinach (medians 5.9-8 µg/kg).[2,5] Where inorganic arsenic was measured directly it averaged 5 µg/kg in Hong Kong, and five of seven European submissions were below a 6 µg/kg reporting limit.[1,27]

Lot results for cadmium and lead on a fresh-weight basis with quantification limits well below 0.20 and 0.30 mg/kg, the growing region and field, and the irrigation water source.[2,3,4] For arsenic-affected regions, the arsenic content of irrigation water.[24]

References

[1] GEMS/Food Contaminants database heavy-metal exports
World Health Organization · GEMS/Food Contamination Monitoring and Assessment Programme · 2026 · extranet.who.int
DATASET

[2] FY2018-FY2020 TDS Elements Analytical Results
U.S. Food and Drug Administration · FDA Total Diet Study · 2022 · www.fda.gov
DATASET

[3] Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006
European Commission · Official Journal of the European Union · 2023 · eur-lex.europa.eu
REGULATION

[4] Heavy metal accumulation in leafy vegetables grown in industrial areas under varying levels of pollution
Naser HM, Rahman MZ, Sultana S, Quddus MA, and Hossain MA · Bangladesh Journal of Agricultural Research · 2018 · doi.org/10.3329/bjar.v43i1.36157
PEER-REVIEWED

[5] Evaluation of essential, toxic and potentially toxic elements in leafy vegetables grown in the Canary Islands
Veronica Martin-Leon, Carmen Rubio, Angel Rodriguez-Hernandez, Manuel Zumbado, Andrea Acosta-Dacal, Luis Alberto Henriquez--Hernandez, et al. · Toxics · 2023 · doi.org/10.3390/toxics11050442
PEER-REVIEWED

[6] Mitigating Toxic Metal Exposure Through Leafy Greens: A Comprehensive Review Contrasting Cadmium and Lead in Spinach
Seyfferth AL, Limmer MA, Runkle BRK, and Chaney RL · GeoHealth · 2024 · doi.org/10.1029/2024GH001081
PEER-REVIEWED

[7] Scientific Opinion of the Panel on Contaminants in the Food Chain on a request from the European Commission on cadmium in food
EFSA Panel on Contaminants in the Food Chain (CONTAM) · The EFSA Journal · 2009 · doi.org/10.2903/j.efsa.2009.980
GOVERNMENT

[8] Heavy Metals Assessment in Selected Leafy Vegetables from Selangor, Malaysia
See SN, Pak Dek MS, Sanny M, Shukri R, and Ramli NS · Pertanika Journal of Tropical Agricultural Science · 2025 · doi.org/10.47836/pjtas.48.1.12
PEER-REVIEWED

[9] Compound health risk assessment of cumulative heavy metal exposure: A case study of a village near a battery factory in Henan Province, China
Jiang Y, Ma J, and Ruan X · Environmental Science: Processes & Impacts · 2020 · doi.org/10.1039/D0EM00104J
PEER-REVIEWED

[10] Effects of sewage water irrigation on heavy metals accumulation in vegetables in peri-urban areas of Faisalabad, Pakistan
Muhammad Abubakar, Basit Haider, Hadeeqa Arshad, Tufail Shah, Ameer Khan, Hummera Nawaz, et al. · Agricultural Research Reports 3(1):46–57 · 2025 · doi.org/10.54219/arr.03.1.2025.418
PEER-REVIEWED

[11] BIO-ACCUMULATION OF HEAVY METALS IN SOME NORTH
INDIAN LEAFY VEGETABLES AND QUANTIFICATION OF CONSUMER HEALTH RISK DUE TO THEIR DIETARY INTAKE SHAIL KULSHRESTHA Department of Chemistry, D. B. S. (P. G.) College, Dehradun, and India (· Peer-reviewed article · 2022 · doi.org/10.53550/pr.2022.v41i03.032
PEER-REVIEWED

[12] Baby Foods Are Tainted with Dangerous Levels of Arsenic, Lead, Cadmium, and Mercury
U.S. House of Representatives, Committee on Oversight and Reform, Subcommittee on Economic and Consumer Policy · Staff Report · 2021 · oversight.house.gov
GRAY LITERATURE

[13] The First Hong Kong Total Diet Study: Metallic Contaminants
Centre for Food Safety (Hong Kong) · Centre for Food Safety, Food and Environmental Hygiene Department, Government of the Hong Kong Special Administrative Region · 2013 · www.cfs.gov.hk
GOVERNMENT

[14] Levels of heavy metals and their health risk assessment from wastewater irrigated spinach in railway quarters, Bauchi, Bauchi state, Nigeria
Adebayo RK, Hassan UF, Adamu HM, Hassan HF, Baba H, and Ajiya DA · International Journal of Advanced Chemistry Research · 2020 · doi.org/10.33545/26646781.2020.v2.i2a.22
PEER-REVIEWED

[15] Environmental surveillance of commonly-grown vegetables for investigating potential lead and chromium contamination intensification in Bangladesh
Hossain AMMM, Islam MS, Mamun MM, Al-Jonaed HM, Imran M, Rahman MH, et al. · SpringerPlus · 2016 · doi.org/10.1186/s40064-016-3458-9
PEER-REVIEWED

[16] Concentration and Health Risk Assessment of Selected Heavy Metals (HMs) in African spinach (Amaranthus hybridus) and Tomato (Solanum lycopersicum) Grown around Ashaka Community, Gombe State, Nigeria
Fatai MI, Ibrahim M, Ibrahim MA, Ndriza BJ, Matthew EO, Saheed MB, et al. · Journal of Chemistry and Nutritional Biochemistry · 2024 · doi.org/10.48185/jcnb.v5i2.1175
PEER-REVIEWED

[17] Heavy metals in vegetables: screening health risks involved in cultivation along wastewater drain and irrigating with wastewater
Sharma A, Katnoria J K, and Nagpal A K · SpringerPlus · 2016 · doi.org/10.1186/s40064-016-2129-1
PEER-REVIEWED

[18] Toxic elements in baby and young children's foods in the US and correlation to ingredients
Charles A. Barber, Marc Boyer, Jake A. Carter, Patrick J. Gray, Jennifer Fong Sam, and Mesay M. Wolle · Food Additives & Contaminants: Part B · 2025 · doi.org/10.1080/19393210.2025.2591749
PEER-REVIEWED

[19] Heavy Metals in Commonly Consumed Root and Leafy Vegetables in Dhaka City, Bangladesh, and Assessment of Associated Public Health Risks
Sultana R, Tanvir RU, Hussain KA, Chamon AS, and Mondol MN · Environmental Systems Research · 2022 · doi.org/10.1186/s40068-022-00261-9
PEER-REVIEWED

[20] The health risk assessment of heavy metals in vegetables grown in Babol city, Iran
Abdolahpour Alamdari H, Sleman Ali H, Sadighara P, Jahed Khaniki G, Shahsavanpoor Landeh K, and Dehghani MH · International Archives of Health Sciences · 2023 · doi.org/10.48307/IAHSJ.2023.177176
PEER-REVIEWED

[21] Ultra-Sensitive Determination of Cadmium in Food and Water by Flame-AAS after a New Polyvinyl Benzyl Xanthate as an Adsorbent Based Vortex Assisted Dispersive Solid-Phase Microextraction: Multivariate Optimization
Altunay N, Hazer B, Lanjwani MF, and Tuzen M · Foods 2023, 12, 3620 · 2023 · doi.org/10.3390/foods12193620
PEER-REVIEWED

[22] Heavy Metals in Soil and Vegetables and their Effect on Health
Pal Jitender, Bishnoi Mukal, and Kaur Mandeep · International Journal of Engineering Science Technologies · 2017 · doi.org/10.29121/IJOEST.v2.i1.2017.03
PEER-REVIEWED

[23] Heavy metals in vegetables and the health risk to population in Zhejiang, China
Huang Z, Pan XD, Wu PG, Han JL, and Chen Q · Food Control · 2014 · doi.org/10.1016/j.foodcont.2013.08.036
PEER-REVIEWED

[24] Uptake of Arsenic by Irrigated Vegetables and Cooked Food Products in Burkina Faso
Clair-Caliot G, Marks SJ, Hug SJ, Bretzler A, N'guessan ND, Tihe SFK, et al. · Frontiers in Water · 2021 · doi.org/10.3389/frwa.2021.667308
PEER-REVIEWED

[25] compared to the chemical fertilizer. In organic fertilizer applications, heavy metal contents such as arsenic, chrome, cobalt, and nickel were found to
Unknown authors · Peer-reviewed article · 2022 · doi.org/10.24180/ijaws.1094410
PEER-REVIEWED

[26] The Cd:Zn ratio in a soil affects Cd toxicity in spinach (Spinacea oleracea L.)
Tajammal Hussain, Ghulam Murtaza, Abdul Ghafoor, and Mumtaz Akhtar Cheema · Pakistan Journal of Agricultural Sciences · 2016 · doi.org/10.21162/PAKJAS/16.5216
PEER-REVIEWED

[27] The First Hong Kong Total Diet Study: Inorganic Arsenic
Centre for Food Safety FEHD HKSAR · Centre for Food Safety, Food and Environmental Hygiene Department, Government of the Hong Kong Special Administrative Region · 2012 · www.cfs.gov.hk
GOVERNMENT

[28] A review on the concentration of the heavy metals in vegetable samples like spinach and tomato grown near the area of Amba Nalla of Amravati City
Mohod CV · International Journal of Innovative Research in Science, Engineering and Technology · 2015 · doi.org/10.15680/IJIRSET.2015.0405019
PEER-REVIEWED

[29] Minimization of cadmium toxicity and improvement in growth and biochemical attributes of spinach by using acidified biochar
Laraib Sheikh, Nargis Naz, Sadaf Oranab, Uzma Younis, Abdullah A. Alarfaj, Sulaiman Ali Alharbi, et al. · Scientific Reports · 2025 · doi.org/10.1038/s41598-025-90746-1
PEER-REVIEWED

[30] chromium through Cr-stressed Life Sciences, Faculty of Food Science and Technology, University of Agricultural Sciences and
Unknown authors · Peer-reviewed article · 2022 · doi.org/10.3389/fpls.2022.973740
PEER-REVIEWED

[31] Muhammad Shoaib Rana, gel alleviates chromium
Unknown authors · Peer-reviewed article · 2026 · doi.org/10.3389/fpls.2026.1786570
PEER-REVIEWED

[32] Article 2. Common Standards and Specifications for General Foods
Korea Food and Drug Administration · Korean Food Code · 2012
REGULATION

[33] Guidelines on the Food Adulteration (Metallic Contamination) (Amendment) Regulation 2018
Centre for Food Safety, Food and Environmental Hygiene Department, and Government of the Hong Kong Special Administrative Region · USDA Foreign Agricultural Service GAIN Report HK1922, relaying the Hong Kong Centre for Food Safety Guidelines for the Food Adulteration (Metallic Contamination) (Amendment) Regulation 2018 (Cap. 132V sub. leg.) · 2019 · apps.fas.usda.gov
GOVERNMENT

[34] Commission Regulation (EU) 2024/1987 of 30 July 2024 amending Regulation (EU) 2023/915 as regards maximum levels of nickel in certain foodstuffs
European Commission · Official Journal of the European Union, L series, 2024/1987 (31.7.2024) · 2024 · data.europa.eu
REGULATION

[35] China Releases the Standard for Maximum Levels of Contaminants in Foods (USDA FAS GAIN Report CH2023-0040, unofficial translation of GB 2762-2022)
USDA Foreign Agricultural Service, FAS China Staff (Beijing) · USDA Foreign Agricultural Service, Global Agricultural Information Network (GAIN), Report Number CH2023-0040 · 2023 · www.fas.usda.gov
REGULATION

[36] General Standard for Contaminants and Toxins in Food and Feed (CXS 193-1995)
Codex Alimentarius Commission · Codex Alimentarius (Joint FAO/WHO Food Standards Programme) · 1995 · www.fao.org
GOVERNMENT

[37] Nickel Content of Food and Estimation of Dietary Intake
Mari-Ann Flyvholm, Gitte Dalsgaard Nielsen, and Allan Andersen · Zeitschrift für Lebensmittel-Untersuchung und -Forschung 179(6):427-431 · 1984 · doi.org/10.1007/BF01043419
PEER-REVIEWED

[38] Heavy Metal Contamination of Irrigation Water, Soil, and Vegetables and the Difference between Dry and Wet Seasons Near a Multi-Industry Zone in Bangladesh
Ahmed M, Matsumoto M, Ozaki A, Van Thinh N, and Kurosawa K · Water · 2019 · doi.org/10.3390/w11030583
PEER-REVIEWED

[39] Health Risk Assessment and Multivariate Statistical Analysis of Heavy Metals in Vegetables of Khyber Pakhtunkhwa Region, Pakistan
Ullah H, Khaliq M, Ullah N, Iqbal A, Fozia, and Ullah I · Biological Trace Element Research · 2022 · doi.org/10.1007/s12011-021-02892-y
PEER-REVIEWED

[40] Dataset of metals and metalloids in food crops and soils sampled across the mining region of Moquegua in Peru
Bedoya-Perales NS, Escobedo-Pacheco E, Maus D, Neimaier A, and Pumi G · Scientific Data · 2023 · doi.org/10.1038/s41597-023-02363-0
PEER-REVIEWED

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COMPETING INTERESTS

The Heavy Metal Index reports what the peer-reviewed and regulatory literature supports. It is operated separately from any certification program, does not evaluate or endorse brands, and does not use certification thresholds as evidence for the statements made here.

DATA AVAILABILITY

Every source behind this ingredient profile is listed with its own source record at https://heavymetalindex.com/ingredients/spinach#sources.

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