Dietary nickel has an irreducible botanical floor in specific plant staples, so a large share of dietary nickel cannot be sourced out of a supply chain, and background diets can reach or exceed nickel tolerable-intake reference points without any pollution source

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Abstract

Nickel behaves unlike lead, cadmium, or arsenic in the food supply. For those metals, an elevated concentration in a commodity is usually a signal of contamination somewhere in the supply chain: contaminated soil, an industrial point source, an adulterated spice, or a processing-side transfer. For dietary nickel the elevated concentrations sit predominantly in a specific and predictable set of plant staples (cocoa and chocolate, soybeans and other legumes, oats and whole-grain cereals, and tree nuts and peanuts), and a substantial fraction of that content is present because those plants take up and concentrate nickel as an ordinary feature of their physiology. The claim this page defends is a floor claim rather than an exclusivity claim: nickel in a legume or a cocoa bean cannot be driven toward zero by supply-chain control, because the plant requires the metal to function. It is not the claim that dietary nickel is never a contamination signal, and the sections below set out the soil-geology and post-harvest pathways that add to the botanical floor. Six independent datasets spanning four decades and four jurisdictions converge on the occurrence pattern: the European Union CONTAM Panel's 44,585-sample occurrence and exposure assessment (efsa2015-nickel-food-water), a Danish literature-plus-primary compilation from 1984 (flyvholm1984), a Polish cereal-grain survey from 2020 (mania2020), a Chinese provincial total-diet study from 2024 (han2024), a Polish tree-nut survey from 2025 (cwielag-drabek2025), and an Italian muscle-meat survey from 2025 (manfredi2025). The five plant-focused datasets agree on

which foods carry nickel, in what rank order, and at what magnitude; the meat dataset supplies the confirmatory contrast that animal muscle is, by comparison, a minor nickel source.

1 | Overview

The non-obvious synthesis has two parts. First, the same food ranking recurs across geographies and across forty years of independent measurement, which is the signature of an intrinsic plant trait rather than of purely localized contamination. Second, in the European occurrence and exposure assessment, background dietary nickel intake reaches or exceeds the tolerable daily intake for younger age classes with no pollution source involved at all, which means that treating dietary nickel purely as a contaminant to be sourced out of a supply chain will not work: a large share of the metal is endogenous to the commodities that dominate exposure.

The concentration measured in an edible fraction is better understood as the product of three terms rather than as a single-cause phenomenon. The first is the crop trait, which is the botanical floor this page is named for and which the occurrence data below characterize well. The second is soil supply, which is not zero: nickel uptake is sensitive to soil pH and to parent-material geology, and geogenic nickel from serpentine and other ultramafic parent materials sets a regional floor that agronomy can manage but not remove, as developed on soil-to-plant-transfer. The third is post-harvest handling, where nickel can be added to a food after it leaves the field, most notably through nickel-catalysed hydrogenation of vegetable oils and through leaching from nickel-bearing stainless steel during processing and cooking. The six anchor datasets synthesized here characterize the first term well and the second and third only incidentally, which is a real limit on this page and is stated again in the provisional-status section. Two further honesty caveats run through the whole synthesis and are stated in their own sections below: the operative tolerable daily intake for nickel was revised upward by a factor of roughly 4.6 between 2015 and 2020, so whether background diets exceed the reference point depends on which reference point is applied; and the European occurrence dataset is substantially less geographically independent than its fifteen-Member-State provenance suggests.

2 | The European occurrence and exposure baseline (EFSA CONTAM Panel 2015)

efsa2015-nickel-food-water is the largest and most authoritative anchor. The EFSA Panel on Contaminants in the Food Chain integrated 44,585 admitted occurrence records (18,885 food and 25,700 drinking-water samples) submitted by 15 European Member States for 2003 to 2012, combined them with the EFSA Comprehensive European Food Consumption Database across 26 chronic surveys in 17 countries, and characterized dietary nickel exposure by age class. Analytical results were expressed on a whole-weight (as-analyzed) basis. The occurrence distribution is strongly food-specific. The highest-concentration subgroups were cocoa beans and cocoa products (solid) at a mean of 9,528 micrograms per kilogram (n=238), soybeans at 4,624 to 4,685 micrograms per kilogram, peanuts at 3,537 to 3,569, dried beans at 3,055 to 3,077, chocolate (cocoa) products at 3,231 to 3,236 (n=490), and dry tea and herbs for infusion at 761 to 762. The aggregate legumes, nuts and oilseeds group had a mean of 1,862 (lower bound) to 1,880 (upper bound) micrograms per kilogram with a 95th percentile of 7,000 (n=1,218). Grains and grain-based products had a mean of 271 to 321 micrograms per kilogram with a 95th percentile near 1,069 to 1,078 (n=4,291). At the opposite end, drinking water was the lowest group at a mean of 1 to 2 micrograms per kilogram (n=25,700, 89 percent left-censored), meat and meat products sat at 191 to 239, fish at 77 to 112, and milk and dairy at 71 to 93.

The exposure result is the load-bearing finding. Under the tolerable daily intake the Panel derived in this opinion, 2.8 micrograms of nickel per kilogram of body weight per day, mean chronic dietary exposure was at or above the tolerable daily intake for toddlers, other children, infants, and adolescents, and the 95th-percentile exposure was above the tolerable daily intake for every age class (mean estimates ranged from 2.0 to 13.1, and 95th-percentile estimates from 3.6 to 20.1 micrograms per kilogram of body weight per day across surveys and age classes). The dominant chronic contributors were grains and grain-based products, non-alcoholic beverages (cocoa-based drinks in the young and coffee in adults), sugar and confectionery (chocolate), the legumes-nuts-oilseeds group, and vegetables. In one young-population survey, cocoa-driven non-alcoholic beverages alone accounted for 41.8 percent of total nickel exposure. Drinking water, by contrast, contributed between 0.0005 and 1.7 percent of total dietary nickel. The Panel recorded that no European maximum levels for nickel in food existed as of 2015. That statement was accurate when written and is no longer the current regulatory position: the European Commission set harmonised maximum levels for nickel in 2024, and the regulatory-implications section below works from the levels now in force rather than from the 2015 vacuum.

One structural caveat belongs with this dataset because the synthesis leans on it for geographic reproducibility. The fifteen-Member-State provenance overstates how geographically independent the occurrence data are: approximately 80 percent of the admitted samples came from a single Member State (Germany at 79 percent), with Slovakia at 11 percent and Cyprus at 5 percent. The EFSA dataset is therefore better read as one very large national dataset with a modest multi-country margin than as a pan-European average, and the cross--jurisdictional reproducibility argument this page makes rests more heavily on the independent Danish, Polish, Chinese, and Italian datasets than the raw Member-State count implies.

3 | The Danish precedent (Flyvholm, Nielsen, and Andersen 1984)

flyvholm1984-nickel-content-food-dietary-intake establishes that the same food ranking was already visible four decades before the EFSA opinion, from an entirely separate body of measurement. Working at the Danish National Food Institute and the Danish Toxicology Centre, the authors compiled 2,221 food samples from the post-1969 literature (restricted to samples analyzed by atomic absorption spectrometry or PIXE for reliability) supplemented with their own analyses, and modeled the Danish average diet. The concentration rank order, reported in micrograms per gram (equivalent to milligrams per kilogram), is the same one the EFSA dataset would later produce: cocoa at a mean of 9.8 (n=7), soybeans at 5.2 (n=3), soy products at 5.1, walnuts at 3.6, peanuts at 2.8, oats at 2.3 (n=37), bitter chocolate at 1.9, hazelnuts at 1.8, dried legumes at 1.7, and almonds at 1.3. Within the modeled average diet, oatmeal was the standout per-gram contributor, with a load factor of 24 (the load factor being the ratio of a food's share of total nickel intake to its share of total consumption; any value above 1 means the food contributes nickel disproportionately to its dietary weight).

The intake estimate anchors the exposure side. The Danish average diet delivered 150 micrograms of nickel per person per day from food (over 2,099 grams of food per day, exclusive of drinking water), with tap water adding roughly 16 micrograms per day under normal draw. Substituting high-nickel foods into the average diet raised modeled intake to 900 micrograms per day or more, which the authors placed against the 600 to 5,600 microgram single oral dose range that provoked hand-eczema flare in nickel-sensitized patients under clinical challenge. That a 1984 Danish compilation and a 2015 pan-European assessment, using different samples, different methods, and different populations, produce the same commodity ranking and the same conclusion that ordinary diets carry biologically meaningful nickel loads is the strongest available evidence that the pattern is an intrinsic property of the foods rather than an artifact of any one survey or era.

4 | The Polish cereal-grain signal (Mania 2020)

mania2020-nickel-cereal-grains-poland provides a focused, recent, primary occurrence dataset for the cereal end of the pattern. The authors measured nickel by graphite-furnace atomic absorption spectrometry in 56 cereal-grain and cereal-based product samples from the Polish retail market in 2019 to 2020, reporting concentrations in milligrams per kilogram on an as-purchased product basis with middle-bound substitution for the 27 percent of results below the 0.06 milligrams per kilogram matrix limit of quantification. Whole and less-refined fractions carried the nickel: cereal grains (millet, rye, wheat, barley) had a mean of 1.16 and a 95th percentile of 3.91 milligrams per kilogram, with millet reaching 4.80 and oat flakes 2.53; bran had a mean of 1.34 and flakes 0.93; groats sat at 0.63, flour at 0.35, and pasta at 0.26. The processing gradient is explicit in the data: whole-grain flour ranged up to 2.12 milligrams per kilogram while refined wheat flour fell below the limit of quantification, and whole-grain pasta reached 1.79 while regular wheat-flour pasta ranged only 0.03 to 0.08. This is consistent with nickel being concentrated in the bran and germ fractions that refining removes, which is a milling-physics observation rather than a contamination observation. The authors assessed exposure against the revised 2020 tolerable daily intake of 13 micrograms per kilogram of body weight per day, and under that reference point cereal grains excluding rice contributed 13.4 percent of the tolerable daily intake for adults at mean contamination, while a child 95th-percentile cereal-product scenario reached 11.8 percent.

5 | The Chinese total-diet signal (Han 2024)

han2024-nickel-zhejiang-china extends the pattern to an East Asian total-diet context and to a different regulatory frame. The authors measured nickel by ICP-MS in 2,628 food samples collected across 11 cities of Zhejiang Province in 2018 to 2019 and paired the concentrations (reported in milligrams per kilogram, fresh-food basis) with a consumption survey of roughly 19,000 individuals. Beans were the clear high-nickel outlier: the bean category (n=5) had a mean of 3.094 milligrams per kilogram, and a single soybean sample reached 9.21 milligrams per kilogram (the small sample size is a genuine limit on the strength of the bean inference and is noted as such in the source). The study reports all five bean samples as exceeding a 1 milligram per kilogram figure taken from GB 2762-2022, and that comparison should not be carried forward as a regulatory exceedance. The only nickel maximum level in GB 2762-2022 is 1.0 milligram per kilogram for hydrogenated vegetable oil and for products produced partly from or containing hydrogenated vegetable oil, which is a limit on catalyst carry-over from the hydrogenation process (USDA FAS translation of GB 2762-2022, Table 6, section 4.6). China sets no nickel maximum level for beans, cereals, aquatic foods, or any other food category, so the bean, canned-fish, and shellfish over-standard rates reported in this study are comparisons against a limit that does not cover those matrices. The concentration data stand; the exceedance framing does not. This detail cuts against rather than for the intrinsic-content argument as it was originally stated on this page, because it means the one nickel limit China does set is a process-contamination limit, which is evidence that nickel in food has a genuine post-harvest contamination pathway alongside the botanical floor. The rest of the categories fell in a much lower band: meat and products (n=690) at a mean of 0.258, vegetables (n=365) at 0.185 (with legume vegetables the highest vegetable subgroup at 0.813), aquatic foods (n=1,405) at 0.261, cereal products (n=27) at 0.136, and fruits (n=136) at 0.097. The exposure model found that children aged 0 to 6 were the only population segment reaching an unacceptable cumulative target hazard quotient (1.078) under the high-concentration, high-consumption assumption (95th-percentile concentration multiplied by 95th-percentile consumption), at a modeled total nickel intake of 21.57 micrograms per kilogram of body weight per day. The authors noted that this figure exceeds both the 2015 EFSA tolerable daily intake (2.8) and the revised 2020 value (13), and that beans and vegetables were the dominant contributors. That a Chinese provincial diet, a Danish diet, and a European multi-country diet all place legumes and plant staples at the top of the nickel contribution list is the cross-cultural confirmation of the trait.

6 | The Polish tree-nut signal (Ćwieląg-Drabek 2025)

cwielag-drabek2025-nuts-cd-pb-cr-ni-poland isolates the tree-nut and peanut arm of the pattern with recent market data. The authors measured cadmium, lead, chromium, and nickel by electrothermal atomic absorption spectrometry in 69 nut samples (16 peanuts, 15 hazelnuts, 15 almonds, 8 cashews, 15 walnuts) from the Polish market sourced from 13 countries, reporting concentrations in milligrams per kilogram on a wet-weight basis. Nickel was the most abundant of the four toxic elements measured in nuts and the primary driver of the modeled health risk. Mean nickel concentrations were 6.434 milligrams per kilogram in cashews, roughly 4 in peanuts, and 1.299 in almonds, with an all-nut mean of 3.21; the highest single value was 11.20 milligrams per kilogram in a peanut sample, the highest nickel value across the studies the authors compared. The nickel rank order was cashews above peanuts, then walnuts, hazelnuts, and almonds. The health-risk assessment found that at higher consumption scenarios (50 to 100 grams per day, modeled for children) the cumulative hazard index exceeded 1, driven primarily by nickel. This dataset is independent of Mania 2020 in authorship and institution despite the shared Polish market, and it confirms that nuts belong in the same high-nickel plant-staple tier as cocoa, soy, and oats.

7 | The Italian meat contrast (Manfredi 2025)

manfredi2025-nickel-meat-italy is the confirmatory negative case that sharpens the whole synthesis. The authors measured nickel by ICP-MS in 809 official-control muscle-meat samples collected in Italy from 2011 to 2023, reporting concentrations in milligrams per kilogram. The means were low across all three matrices: poultry (n=156) at 0.016, beef (n=306) at 0.010, and pork (n=347) at 0.009 milligrams per kilogram, with maxima of 0.583, 0.606, and 0.158 respectively and minima below the limit of quantification. The exposure assessment found that meat consumption contributed less than 1 percent of the EFSA nickel tolerable daily intake across all age groups, with the single highest contribution being 0.86 percent from pork in toddlers. Animal muscle, in other words, is roughly two to three orders of magnitude below cocoa, soy, and cashews on nickel, which is exactly what the plant-accumulation hypothesis predicts: nickel enters the food supply through plant physiology, and tissues that do not accumulate it from a plant-uptake pathway stay low. The meat contrast is what distinguishes an intrinsic-plant-trait explanation from a generic "everything is a little contaminated" explanation.

8 | The mechanistic explanation

The reproducibility of the food ranking across jurisdictions and decades is most parsimoniously explained by nickel being taken up from soil by plant roots and translocated into seeds, beans, and grain fractions through the plant's ordinary micronutrient and metal-handling physiology; none of the six anchor datasets measures this uptake pathway directly, so the mechanism is an inference from the reproducible occurrence pattern rather than a measured finding of these sources. Certain taxa appear to concentrate nickel markedly: legumes (including soybeans and peanuts, which is a legume), cocoa, oats and whole-grain cereals, and tree nuts recur at the top of every dataset synthesized here. The concentration is highest in the metabolically active storage fractions, which is why the milling gradient in Mania 2020 is so clean: bran, germ, and whole-grain fractions carry the nickel and refined white flour does not, because refining physically removes the fractions where the plant deposited it. This is mechanistically parallel to the biological-accumulation logic documented for cadmium and arsenic in seaweed, where the elevated metal is a feature of the organism's physiology rather than a quality-control failure, and to the multi-metal uptake documented in tea. The evidence that uptake physiology is doing substantial work, rather than pollution geography alone, is the reproducibility of the food ranking: a purely contamination-driven explanation would predict that the high values track polluted regions and shift with sourcing, whereas the observed pattern is that the same foods rank high in Denmark, across the European Union, in Poland, and in

China, and that a compositionally different tissue (animal muscle, Manfredi 2025) stays low even in the same food system.

That argument establishes a floor, not an exclusive cause, and the page previously overstated it by concluding that nickel concentration is a property of what the commodity is and not of where a lot came from. Origin does matter on top of the trait. Nickel uptake is sensitive to soil pH and to parent-material geology, and serpentine and other ultramafic parent materials carry markedly elevated geogenic nickel that transfers into crops grown on them, which is the framework developed on soil-to-plant-transfer and soil-nickel-screening. The correct formulation is that the commodity sets a floor below which sourcing cannot go, while soil geology and post-harvest handling determine how far above that floor a given lot sits. None of the six anchor datasets here stratifies its samples by soil parent material, so this page cannot quantify the geogenic term, and the size of the origin effect relative to the botanical floor is an open question rather than a settled one.

9 | Why nickel differs in kind from the non-essential toxic metals

The occurrence pattern above is an empirical generalization, and a single badly contaminated shipment could embarrass it. There is a stronger and more durable statement of the same point available, which rests on what nickel is rather than on how foods happen to rank.

Lead is a non-essential metal with no known biological requirement (ATSDR 2020), and the same holds for cadmium, inorganic arsenic, and methylmercury. For those metals a policy target of driving concentrations toward zero is biologically coherent, because no organism in the food chain needs them and nothing is lost from the food by their absence. Nickel is not in that class. It is a required cofactor for enzyme systems that organisms cannot operate without, and the corpus documents this directly on the microbial side: nickel is the essential cofactor for urease and for [NiFe] hydrogenases across at least five virulence-associated enzyme systems, characterized in Maier and Benoit 2019 and developed further on nickel-microbial-pathogenesis. Urease is the enzyme that lets an organism hydrolyse urea, and a plant or microorganism deprived of nickel cannot run it.

This is the structural reason the floor exists, and it separates nickel from the non-essential toxic metals at the level of mechanism rather than at the level of a food ranking that could shift. A commodity can in principle be sourced to near-zero lead; it cannot be sourced to near-zero nickel without compromising the organism that produced it. Any limit for nickel in a plant-derived food is therefore set against a biologically required background, which is what makes the crop-calibrated structure of the European levels the appropriate shape for the instrument.

The plant-physiology literature that would let this page state the mechanism in plants directly, rather than inferring it from the microbial enzymology and the occurrence pattern, is not yet in the corpus. The specific gap is the nickel-urease requirement in higher plants, nickel's role in nitrogen-fixing legume symbiosis, and the agronomic nickel-fertilization trials on nickel-poor soils that would test the floor claim most directly. This gap is logged rather than papered over, and the claim above is scoped to what the corpus currently supports.

10 | Why conventional contaminant surveillance misframes nickel

Conventional heavy-metal surveillance is built around the premise that an elevated result flags a problem to be traced and removed: find the contaminated field, the leaded spice, the industrial outfall, and the concentration falls. That premise is productive for lead, cadmium, and arsenic in many matrices, and it underlies the maximum-level ceiling as the default regulatory instrument. It misframes nickel in two ways. First, the highest-nickel foods are high because of what they are, so there is no upstream source to remove; a cocoa lot, a soybean lot, or a cashew lot that a supplier could realistically deliver will carry nickel in the multi-milligram-per--

kilogram range as a baseline. Second, because nickel is distributed across many regularly consumed staples rather than concentrated in a few flagged commodities, aggregate exposure is driven by the ordinary diet, which is precisely why the EFSA assessment found background mean intake at or above the tolerable daily intake for younger age classes with no contamination event anywhere in the picture. A surveillance program that treats each high nickel result as a defect to be sourced out will chase values that cannot be removed without removing the food, and will still not address the aggregate-exposure problem, which lives in the diet as a whole rather than in any single lot.

The instrument that follows from this is a crop-calibrated ceiling rather than no ceiling. A single across-the-board maximum level set at a contamination-control magnitude would fall below the intrinsic content of cocoa or soy and function as a prohibition of those foods, but that is an argument against a uniform ceiling, not against maximum levels as such. European practice has since resolved the question in exactly that direction, and the resolution is documented in eu-2024-1987-nickel-maximum-levels: the Commission set nickel maximum levels that span more than two orders of magnitude across food categories, from 0.10 milligrams per kilogram for liquid infant formula to 15 for soy beans and cocoa powder, with the level for each category set against that category's own occurrence distribution. A ceiling calibrated per commodity does not collide with the botanical floor, which is why the objection developed in this section applies to the uniform-ceiling instrument and not to the instrument the European Union actually adopted.

11 | The unresolved tolerable-intake reference point

An honest account states plainly that the exceedance claim depends on which health-based reference point is applied, and that this reference point moved substantially. In the 2015 opinion, the EFSA CONTAM Panel derived a chronic tolerable daily intake of 2.8 micrograms of nickel per kilogram of body weight per day, from a benchmark dose lower confidence limit of 0.28 milligrams per kilogram of body weight per day for post-implantation fetal loss in rats, divided by an uncertainty factor of 100. Under that value, background European diets exceeded the reference point at the mean for young age classes and at the 95th percentile for all age classes, and the finding that ordinary diets already breach the tolerable intake is robust. The Panel subsequently revised the chronic tolerable daily intake upward to 13 micrograms per kilogram of body weight per day in its 2020 update, roughly 4.6 times higher, on reconsideration of the dose-response endpoint. Under the 2020 value, most background mean intakes fall below the reference point, and the datasets here reflect this: Mania 2020 finds cereal grains contributing only about 13 percent of the 13-microgram tolerable daily intake for adults, and Han 2024 finds an exceedance (21.57 micrograms per kilogram of body weight per day) only for children aged 0 to 6 under the joint high-concentration, high-consumption assumption. The honest synthesis is therefore that background diets clearly reach or exceed the 2015 reference point and reach it primarily for young children and high-consumption scenarios under the 2020 reference point. Two further caveats belong alongside this. The acute reference point moved as well, and the operative value is the later one. The 2015 opinion derived an acute reference point of 1.1 micrograms per kilogram of body weight for nickel-sensitized individuals; the 2020 update instead identified eczematous flare-up reactions (systemic contact dermatitis) in nickel-sensitized humans as the critical acute effect with a lowest-observed-adverse-effect level of 4.3 micrograms of nickel per kilogram of body weight, assessed by a margin-of-exposure approach in which a margin of at least 30 is considered of low concern (EFSA 2020). For the roughly 15 percent of the population who are nickel-sensitized, that margin of 30 is not achieved at either mean or 95th-percentile dietary exposure, which the Panel concluded raises an acute health concern. This is the point that most deserves emphasis, because the upward revision of the chronic tolerable daily intake did not relieve it and in fact left it as the binding health concern for dietary nickel: the acute sensitized-subpopulation finding, not the chronic reference point, is the scientific basis the Commission recited when it set the 2024 maximum levels. The concern connects to combined-exposure-underprotection.

And several of the high-magnitude subgroup means rest on small samples (cocoa n=238 is robust, but Han's bean category is n=5 and Flyvholm's cocoa and soy figures rest on fewer than ten samples each), so the concentration ranking is far better supported than any single subgroup point estimate.

12 | What the evidence implies for testing, regulation, and consumption

For testing, nickel screening should be targeted by commodity composition rather than applied as a uniform contamination screen. The foods that carry nickel are predictable (cocoa and chocolate, soy and other legumes, peanuts and tree nuts, oats and whole-grain and bran cereal fractions), and a product's likely nickel load can be estimated from its ingredient list before any measurement, with whole-grain and less-refined fractions weighted higher than refined ones and animal-muscle ingredients weighted very low. Direct measurement remains the confirmation, but the prior is strong and stable across geographies. Two screening triggers sit outside the botanical prior and should be applied alongside it. A product containing hydrogenated or partially hydrogenated vegetable oil carries a nickel-catalyst carry-over pathway that has nothing to do with the crop, which is the pathway China's single nickel maximum level addresses. And metal cookware is a quantified post-harvest transfer route for nickel: Alrajhi and Idriss 2021 measured nickel release of 0.002 to 0.213 milligrams per litre into distilled water boiled for 30 minutes in imported metallic cookware, with the pathway developed in full on cookware-utensil-metal-leaching-pathway. A screen built only on the botanical prior will miss both.

For regulation, the evidence argues against a single across-the-board maximum-level ceiling as the primary instrument for dietary nickel, and in favour of ceilings calibrated commodity by commodity. Because a large share of the concentration is intrinsic to the commodity, a uniform ceiling set at a contamination-control level would fall below the natural content of cocoa, soy, or cashews and operate as a prohibition of those foods rather than as a contamination limit. A nickel limit for cocoa, legume, or nut products is therefore setting a level against a partly intrinsic content, which makes it a policy choice about acceptable exposure rather than the same kind of number as a lead or cadmium contamination limit, and it means the level has to be read against the commodity's own distribution to mean anything.

Commission Regulation (EU) 2024/1987 is the worked example and is now the governing European instrument, applying from 1 July 2025 for most categories and from 1 July 2026 for cereals (eu-2024-1987-nickel--maximum-levels). Its structure is precisely the crop-calibrated one this evidence implies. Soy beans and cocoa powder are set at 15 milligrams per kilogram, peanuts and dry beans and dry lupins at 12, the tree-nut group containing chestnuts, pine nuts, walnuts, Brazil nuts and cashews at 10, chocolate and milk chocolate at or above 30 percent dry cocoa solids at 7.0, oats at 5.0, pulses at 4.0, cereals generally at 0.80, leafy vegetables at 0.50, fruiting vegetables at 0.40, and liquid infant formula at 0.10, with a separate and higher level of 0.40 for soy-protein-isolate infant formula powder against 0.25 for other formula powder. That last split is the clearest confirmation of the argument on this page: the law itself recognizes that a soy-based product carries a higher botanical nickel floor than a milk-based one and writes the difference into the limit rather than forcing soy formula to meet a level its raw material cannot reach. Where a regulator splits a limit by formulation in this way, the split is evidence about the floor and should be read as such.

The same reasoning is why organic certification does not lower nickel content, for the reason developed in organic-certification-not-protective: the metal enters largely through plant uptake rather than through synthetic agricultural inputs.

For consumers, the actionable statements are specific and dose-anchored rather than framed as "avoid nickel." Cocoa and dark or bitter chocolate, soybeans and soy products, peanuts and tree nuts (cashews in particular, at a mean near 6.4 milligrams per kilogram wet weight), and oats and whole-grain cereals are the dietary staples that contribute most nickel, at multi-milligram-per-kilogram concentrations, whereas meat, fish, dairy, fruit, and refined grains are minor contributors below a few tenths of a milligram per kilogram. For the general population these foods are not a reason for concern under the 2020 reference point at typical intakes, and they carry well-established nutritional value. The two populations for whom the load is more than academic are young children eating high-nickel staples at high frequency (the group for which Han 2024 modeled an exceedance) and the subset of individuals with diagnosed nickel allergy or systemic nickel allergy syndrome, for whom the relevant clinical literature describes low-nickel dietary management that targets exactly these staples; the single-dose oral-challenge range that provoked flare in sensitized patients in Flyvholm 1984 (600 to 5,600 micrograms) is reachable by substituting high-nickel foods into a day's diet. A consumer-facing claim about nickel should always specify which of these populations it addresses, at what intake, and at what frequency, because a statement that is accurate for a nickel-allergic toddler eating oatmeal and cocoa daily is not accurate for a general-population adult.

13 | Provisional status

This synthesis was established 2026-07-27 on six independent anchor sources: one pan-European A-tier occurrence and exposure assessment, one foundational Danish A-tier compilation, two Polish A-tier market surveys (cereals and nuts, from distinct author groups), one Chinese A-tier total-diet study, and one Italian A-tier meat survey supplying the low-nickel contrast. It was substantially revised 2026-08-11 following an external review, and the revision was a correction rather than an extension. Three statements in the original were wrong and have been fixed: the claim that no European maximum level for nickel existed (Commission Regulation (EU) 2024/1987 had been in force for most categories since 1 July 2025 and for cereals since 1 July 2026, and had been ingested into this wiki on 2026-06-22, so the original page contradicted the corpus it was built from); the characterization of a Chinese 1 milligram per kilogram figure as a national limit applicable to beans, when GB 2762-2022 sets that level only for hydrogenated vegetable oil and products containing it; and the framing of dietary nickel as an intrinsic trait rather than a contamination signal, which overstated a floor claim into an exclusivity claim and suppressed the geogenic-soil and post-harvest pathways.

The concentration ranking and the botanical-floor conclusion are robust across four decades and five jurisdictions, with the Italian meat survey serving as the low-nickel contrast case, but that jurisdictional count should be read against the geographic-skew caveat above, since roughly 80 percent of the European occurrence data came from Germany alone. The live uncertainties, carried explicitly in the body, are the roughly 4.6-fold upward revision of the chronic tolerable daily intake between the 2015 and 2020 EFSA opinions, the small sample sizes behind several individual high-magnitude subgroup means, the unquantified size of the geogenic soil term relative to the botanical floor, and the absence from the corpus of the plant-physiology literature that would let the nickel-essentiality mechanism be stated directly rather than inferred. Resynthesis triggers fire when the corpus gains a source that contradicts the commodity ranking, resolves the sensitized-subpopulation acute-exposure question, quantifies crop nickel against soil parent material, or establishes the plant nickel-urease requirement directly.

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REVIEW

STATUS AND LICENCE

Editorially reviewed in-house; no external peer review has been completed on this finding. Published as a preprint with its review state tracked on the article page. Released under CC BY 4.0.

DATA AVAILABILITY

Every source behind this finding is listed with its own extraction record at https://heavymetalindex.com/synthesis/-dietary-nickel-plant-staple-accumulation#sources, each linking to the ingest receipt, the extracted values, and the file hash of the document it was built from.

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.

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