Edible seaweed and kelp are a systematic Cd and As exposure pathway that conventional food-safety surveillance does not adequately characterize

Karen Pendergrass · · Heavy Metal Index, Institute of Contaminant Standards

CITE AS

Pendergrass K. "Edible seaweed and kelp are a systematic Cd and As exposure pathway that conventional food-safety surveillance does not adequately characterize". Heavy Metal Index, 2026. https://-heavymetalindex.com/synthesis/seaweed-cd-as-contamination. CC BY 4.0.

CORRESPONDENCE

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

KEYWORDS

Cd, tAs, iAs, Pb, heavy metals, food safety, dietary exposure

PUBLICATION HISTORY

First published 2026-05-16.

Abstract

Three independent A-tier datasets — a 12-site spatial-temporal survey of New Zealand kelp, a 43-site Salish Sea contaminant assessment across three commercially harvested brown seaweeds, and the EFSA CONTAM Panel's full European-population dietary exposure assessment built on more than two thousand occurrence data points — converge on a single finding: commercial edible seaweed and kelp products carry systematically elevated cadmium and arsenic concentrations that conventional terrestrial-food-chain surveillance frameworks do not capture.

1 | Overview

The finding is distinct from the established organoarsenical inertness synthesis, which addressed the toxicological status of organic-arsenic species in seafood, fungi, microalgae, and seaweed. That synthesis is about the assumption that organoarsenicals are biologically inert. This synthesis is about the contamination magnitude and the regulatory blind spot at the product-distribution end of the supply chain. The two synthesis pages are complementary: the inertness synthesis tells us we cannot read total arsenic minus inorganic arsenic as "the safe part"; this synthesis tells us the totals themselves are large enough that the framing question matters at population scale.

2 | The New Zealand kelp signal (Nepper-Davidsen 2023)

Nepper-Davidsen, Glasson, Lawton, and Magnusson 2023, published in the Journal of Applied Phycology, surveyed Ecklonia radiata kelp at 12 sites across the North Island of New Zealand with 12 additional monthly temporal samples at a single reference site, total n=24 ICP-MS homogenates of six specimens each. The mean

total arsenic concentration was 49 ppm dry weight (range 40.0 to 64.4 ppm DW across sites); the mean cadmium was 1.2 ppm DW (range 0.4 to 2.2 ppm); mean lead was 0.3 ppm DW with one site at 0.7 ppm; mean mercury was below 0.04 ppm DW at every site. Significant temporal autocorrelation was detected for arsenic and mercury at the reference site, meaning a single-time-point measurement at any one harvesting cycle does not characterize the annual exposure profile. Ecklonia radiata is being developed as a New Zealand aquaculture target, so the product-safety implications are direct.

The paper does not speciate arsenic. Brown algae arsenic is predominantly organoarsenic forms — arsenobetaine, arsenosugars, and arsenolipids — but the iAs fraction is not zero and the speciation-specific safety implication cannot be derived from total arsenic alone. The paper's 49 ppm DW tAs mean is the load-bearing number for the wiki: a hypothetical 1 percent iAs fraction would deliver 490 ppb iAs DW per serving, which on a typical 5 g dried-kelp serving translates to 2.45 µg of inorganic arsenic per serving and saturates a meaningful fraction of the EFSA BMDL01 reference exposure window for an adult.

3 | The Salish Sea signal (Hahn 2022)

Hahn et al. 2022, published in PLOS ONE, sampled three edible brown seaweed species (Fucus distichus, Macrocystis pyrifera, Nereocystis luetkeana) at 43 sites across the Salish Sea spanning coastal Washington State and southern British Columbia, n=58 ICP-MS samples. The headline finding: cadmium exceeded international regulatory limits at every site for at least one species, with bull kelp (Nereocystis luetkeana) mean Cd 5.69 mg/kg DW. Fucus distichus mean Cd was 2.52 mg/kg DW; tAs mean was 26.8 mg/kg DW with sites reaching 37 mg/kg. The maximum Pb spike was 13.2 mg/kg DW at an industrial-adjacent site, indicating that recreational-harvest sites near coastal industrial infrastructure inherit additional point-source Pb on top of the systematic Cd and As load.

The Salish Sea is a temperate, industrialized coastline with a long history of indigenous, recreational, and increasingly commercial seaweed harvest. The site-uniformity of the Cd exceedance is the load-bearing observation: the contamination is not site-specific in the sense of one bad bay versus several clean ones; the regional-scale baseline itself exceeds international consumption-safety limits for Cd, across all 43 sites and across all three species. The authors conclude explicitly that current international standards may be inadequate to protect frequent consumers of locally harvested seaweed.

4 | The EFSA regulatory anchor (EFSA 2023)

EFSA CONTAM Panel 2023 is the definitive EU-level scientific opinion on heavy metals in seaweeds and halophytes as food. The opinion analyzed 2,093 Cd occurrence data points, 1,988 Pb, 1,934 tAs, 920 iAs, and 1,499 tHg data points across the seaweed species relevant to European food markets, including laver, kombu, kelp, nori, spirulina, and chlorella. Laver red algae exhibited the highest Cd, reaching 1,675 to 1,676 µg/kg on a wet-weight basis (which translates upward by roughly an order of magnitude on a dry-weight basis as consumed in dried seaweed products). Kombu and kelp had among the highest iAs concentrations of any food matrix in the EU dataset.

The opinion concludes that seaweed consumption — particularly Asian-style dried seaweed products and seaweed-containing food supplements — is a meaningful contributor to dietary heavy-metal exposure for European consumers, with the iAs contribution from seaweed food supplements potentially approaching or exceeding the BMDL01 for some high-consumption scenarios. EFSA's framing is the regulatory anchor for this finding: this is not a contested or emerging finding; the EU's contaminants panel has formally assessed it and concluded that the existing regulatory framework does not adequately characterize the exposure pathway.

5 | The mechanistic explanation

Seaweeds and kelps are biological accumulators of trace elements from the seawater they grow in. Brown algae in particular bind cadmium through algal-cell-wall alginate polysaccharides; the chemical mechanism is durable across species and ocean basins. Arsenic accumulation in brown algae is dominated by uptake into arsenosugars and arsenolipids via the same metabolic pathways that handle phosphate; arsenic is metabolized into stable organic forms but is not excluded from accumulation. The two metals therefore co-elevate in commercial brown-algae products through fundamental biology, not through localized contamination, and the elevation tracks ocean concentrations rather than agricultural or processing-side drivers.

This is mechanistically distinct from terrestrial food contamination. A rice plant grown in low-Cd soil produces low-Cd rice; an apple from a clean orchard is low in Pb. A kelp specimen grown in a clean coastal site is not low in Cd. The accumulation factor for brown algae from typical coastal seawater Cd (low ng/L) to product (mg/kg DW) is roughly 10^5 to 10^6; even nominally clean ocean water delivers enough Cd to push the biological tissue concentration above terrestrial-commodity regulatory limits. Cadmium contamination in seaweed is a biological feature of the product class, not a quality-control failure.

For lead, the picture is different. Lead is not bioaccumulated by brown algae through a comparable high-affinity pathway, so background Pb in commercial seaweed is generally low and the elevated values (such as the 13.2 mg/kg Salish Sea site in Hahn 2022) reflect proximity to point-source Pb deposition (industrial outflow, antifouling paint, harbor sediment). The Pb risk in seaweed is therefore a sourcing-and-screening problem in the conventional sense; the Cd and As risks are not.

6 | Why conventional food surveillance has missed this

Conventional food-safety surveillance frameworks are built around terrestrial commodity matrices: cereals, fruit, vegetables, meat, dairy, fish. Seaweed enters most national food databases either as a minor entry in the "other algae" category or not at all. The 2,093-record EFSA dataset is the result of the panel pulling occurrence data from many specialized sources rather than a routine national-monitoring stream. The USDA FoodData Central database does not list seaweed-specific heavy-metal occurrence in any structured form. The FDA Total Diet Study has minimal seaweed coverage.

The consequence is that dried seaweed snacks, kelp supplements, spirulina powders, and seaweed-containing meal-replacement products sit in a category where the contamination magnitudes are large, the regulatory limits are inconsistently applied across jurisdictions, and the consumer assumption is generally that "sea vegetable" is a healthy minimally-processed food. The category combines a high-magnitude contamination problem with a low-surveillance signal and a positive consumer perception.

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

Because cadmium and inorganic arsenic in seaweed are a biological feature of the product class rather than a site-specific quality-control failure, total arsenic alone does not characterize the toxicologically relevant exposure. Speciation matters: the safety-relevant quantities are cadmium and inorganic arsenic (not total arsenic), and characterizing a seaweed product against the analyte set the EFSA opinion monitors requires measuring Cd and iAs directly rather than inferring them from tAs. The three-source preponderance documented here, the EFSA regulatory positioning, and the biological-feature nature of the Cd contamination together make seaweed and kelp a category where the contamination is foreseeable from the published literature.

On the regulatory side, the EU has a formal CONTAM opinion on seaweed; the US FDA has guidance on iAs in rice cereal but no comparable seaweed-specific limit-setting in force. This regulatory asymmetry is itself a load-bearing finding. US-market seaweed-snack and kelp-supplement products are sold under a framework where the iAs and Cd content is unconstrained by any federal product-specific limit; state-level Prop 65 enforcement is the only operative pressure, and that operates through a different mechanism than the FDA Closer to Zero or EU 2023/915 frameworks. The literature synthesized here supports the case for harmonized seaweed-specific limit-setting in the US.

For consumers, seaweed and kelp products are not low-heavy-metal foods. Consumers concerned about heavy-metal exposure should treat seaweed-containing products as a meaningful contributor to Cd and iAs intake. Marketing seaweed as a "superfood" or "sea vegetable" without reference to its heavy-metal content runs against the available evidence, and organic certification (per organic-certification-not-protective) does not address the contamination mechanism here, because the cadmium and arsenic enter the tissue through algal physiology rather than through agricultural inputs. The quality signal that distinguishes products in this category is direct occurrence testing for Cd and iAs.

8 | What this synthesis does not yet rest on

A US-specific FDA-equivalent occurrence dataset for the US retail market is not in the corpus. The Hahn 2022 Salish Sea dataset is the closest US-relevant anchor but represents harvested-from-coast biological material rather than commercial-retail product. A US retail-market survey across the major commercial seaweed-snack and kelp-supplement product lines would meaningfully strengthen the occurrence evidence for the US retail product class and is a candidate for a Journal of Food Metallomics paper.

Spirulina and chlorella are mentioned in the EFSA dataset and warrant their own treatment. They are biologically distinct from brown-algae kelp (spirulina is a cyanobacterium; chlorella is a green microalga) and the contamination mechanism for As in microalgae is different from the brown-algae mechanism described here. The organoarsenical-inertness-assumption page covers the speciation question for microalgae; the magnitude question for spirulina and chlorella Cd is not yet synthesized.

Iodine, which is the other major safety concern for kelp consumption (high iodine can cause thyroid dysfunction), is outside the scope of this synthesis but warrants a parallel page if iodine becomes part of the wiki's analyte vocabulary. The EFSA 2023 opinion covers iodine as part of the same scientific opinion.

The Cd-bioaccumulation magnitude across non-brown-algae species (red algae such as nori and laver, green algae such as sea lettuce) is documented in EFSA 2023 but not yet broken out into species-specific source pages for the wiki. A targeted ingest pass on species-level seaweed Cd literature would strengthen the per-species component of the ingredient pages.

9 | Implications for downstream wiki pages

seaweed should be developed with this synthesis as the load-bearing reference for the Cd and tAs profile, with the EFSA 2023 numbers as the regulatory anchor. The page should distinguish brown algae (high Cd, high tAs), red algae (highest Cd in laver), and green algae (variable) explicitly.

kelp, laver, kombu, wakame, and nori should each carry their species-specific contamination profile when stub pages are created or upgraded.

seaweed-snacks should be developed as a product-category page with this synthesis as the literature anchor for the Cd, iAs, and tAs occurrence profile.

dietary-supplements should carry a subsection on kelp-supplement Cd and iAs as a distinct risk pathway within the supplement category, separate from the organic certification null finding and from the spice-adulteration synthesis.

The wiki's overview should reference seaweed-as-a-Cd-pathway alongside the established rice-as-an-iAs--pathway and cocoa-as-a-Cd-pathway findings; the three together are the major non-obvious commodity-level Cd and As contributors that the wiki has identified.

10 | Provisional status

This synthesis was established 2026-05-16 on three anchor sources and is provisional pending integration of US-market commercial-product surveys and species-level breakouts. The EFSA regulatory anchor is durable; the magnitude numbers are robust across three independent geographic regions; the biological-mechanism claim is supported by the algal-physiology literature and does not depend on any single source. Resynthesis triggers fire on the next two independent A-tier sources confirming or contradicting either the magnitude or the surveillance-blind-spot finding.

References

[1] High spatial and temporal variation in biomass composition of the novel aquaculture target Ecklonia radiata
Nepper-Davidsen J, Glasson CRK, Lawton RJ, and Magnusson M · Journal of Applied Phycology · 2023 · doi.org/10.1007/s10811-023--02969-2
REVIEW

[2] Chemical contaminant levels in edible seaweeds of the Salish Sea and implications for their consumption
Hahn ME, Schultz IR, Ylitalo GM, Boyd D, Sloan CA, Niewolny LA, et al. · PLOS ONE · 2022 · doi.org/10.1371/journal.pone.0269269
REVIEW

[3] Dietary exposure to heavy metals and iodine intake via consumption of seaweeds and halophytes in the European population
European Food Safety Authority (EFSA), Dujardin B, Ferreira de Sousa R, and Gomez Ruiz JA · EFSA Journal · 2023 · doi.org/10.2903/j.-efsa.2023.7798
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.

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 finding is listed with its own extraction record at https://heavymetalindex.com/synthesis/-seaweed-cd-as-contamination#sources, each linking to the ingest receipt, the extracted values, and the file hash of the document it was built from.

PUBLICATION HISTORY

First published 2026-05-16. The full dated record is maintained at https://heavymetalindex.com/synthesis/-seaweed-cd-as-contamination.