

Bivalve cadmium amplification through filter feeding — why mussels and oysters carry an order-of-magnitude higher cadmium load than finfish

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

CITE AS

Pendergrass K. "Bivalve cadmium amplification through filter feeding — why mussels and oysters carry an order-of-magnitude higher cadmium load than finfish". Heavy Metal Index, 2026. <https://heavymetalindex.com/synthesis/bivalve-cadmium-amplification>. 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, Pb, tHg, heavy metals, food safety, dietary exposure

PUBLICATION HISTORY

First published 2026-05-18.

Abstract

Cadmium concentrations in bivalve molluscs (mussels, clams, oysters, scallops) and cephalopods (squid, octopus, cuttlefish without viscera) are consistently one-to-two orders of magnitude higher than cadmium in finfish muscle from the same waters. The mechanism is filter feeding: bivalves process hundreds of liters of seawater per day, concentrating dissolved and particulate-bound Cd from the water column into their soft tissue. EU regulation acknowledges the differential by setting a 1.0 mg/kg wet-weight Cd cap for bivalves and cephalopods (without viscera) vs the 0.05 mg/kg default for fin-fish muscle — a 20-fold permitted ceiling reflecting the biological reality that bivalves accumulate Cd at qualitatively different rates than fish do.

1 | Overview

Because the bivalve and finfish cadmium distributions are separated by one-to-two orders of magnitude, a single cadmium concentration threshold applied across the whole seafood category is not scientifically supportable: a threshold set near the finfish distribution would exclude nearly all bivalves regardless of how clean the source water is, while a threshold set near the bivalve distribution would fall well above the finfish distribution and discriminate poorly among finfish. EU regulation reflects this by setting separate per-category cadmium ceilings, and the bivalve-specific evidence base is the appropriate reference distribution for any bivalve cadmium benchmark.

2 | The bivalve-finfish Cd differential

Across the wiki's seafood-axis evidence base, the Cd concentration pattern is:

- **Finfish muscle (most species, wild and farmed):** typically 0.005–0.05 mg/kg wet weight. Hussein 2023 Egyptian fish dataset (n=120, 6 species) reports Cd means 0.03–0.13 mg/kg across species. Rusko 2026 Latvian inland freshwater fish (n=460, 7 species) reports Cd ALL below LOQ. Cardoso 2023 Portuguese coastal finfish typically below the EU 0.05 mg/kg fin-fish cap.
- **Bivalves (mussels, clams, oysters):** typically 0.1–1.0 mg/kg wet weight, with regional outliers approaching the EU 1.0 mg/kg bivalve cap. Bruno 2024 reports Sicilian lagoon mussel/clam Cd values approaching the EU bivalve cap in specific sub-locations. Dogruyol 2024 Mediterranean mussel survey reports Cd at consumer-relevant concentrations supporting weekly-intake risk modeling. Bao 2024 uses single-particle ICP-MS to characterize Cd nanoparticle forms in mussels in addition to total Cd; the nanoparticle form is a load-bearing finding because nanoparticle-bound Cd has potentially different bioavailability than dissolved Cd.
- **Cephalopods (squid, octopus, cuttlefish, muscle/mantle without viscera):** typically 0.1–0.5 mg/kg wet weight. Cephalopod viscera (digestive gland) concentrate Cd at much higher levels (often >5 mg/kg) and are typically excluded from the EU cap accordingly.
- **Cd-rich bivalve species (scallops, certain oysters):** can approach or exceed the EU 1.0 mg/kg cap routinely; characterizing these species reliably requires source-by-source pooling at the species level rather than relying on the broader bivalve aggregate, because the species-level distributions diverge from the pooled bivalve distribution.

The 10–100× differential between finfish-muscle Cd and bivalve Cd is consistent across all geographies and seasons in the wiki's evidence corpus. This is not measurement noise; it is a biological feature of filter feeding.

3 | The mechanism

Bivalves feed by pumping seawater through their gills and trapping suspended particles and dissolved organic matter for ingestion. Filtration rates are species- and size-dependent but typically range 1–5 liters per hour per individual; an adult mussel can process 50–100 liters per day, an adult oyster substantially more. Dissolved Cd (Cd^{2+} ion and Cd-bound organic complexes in seawater) and particulate Cd (Cd adsorbed to suspended phytoplankton, detritus, and inorganic colloids) are both extracted across the gill epithelium and transported to the digestive gland, gill, and mantle tissue.

Cd uptake in bivalves is non-regulated at the cellular level — metallothionein binding sequesters Cd in soft tissue without active excretion, so bivalves accumulate Cd over their entire lifespan and grow it linearly with size and age. Larger, older bivalves carry more Cd. Sediment-burrowing bivalves (clams) accumulate Cd from sediment porewater as well as water-column filtration, adding a second pathway absent in suspended-rope-grown mussels.

Cephalopods are not filter feeders, but they accumulate Cd through prey consumption and their high metabolic rate concentrates dietary Cd in muscle and viscera. The digestive gland (hepatopancreas) is the primary Cd accumulation site, which is why EU regulation excludes "without viscera" from the cephalopod Cd cap.

4 | The Pb and Hg comparison (for completeness)

Pb in bivalves and cephalopods is generally lower than in finfish, often below the EU 0.50 mg/kg crustacean/bivalve cap. Pb biomagnification is weaker than Cd biomagnification in the filter-feeding pathway because Pb^{2+} adsorbs less efficiently to phytoplankton and is excreted more readily through bivalve digestive processes.

Hg (specifically MeHg) in bivalves and cephalopods is generally similar to or lower than in low-trophic-level finfish. Bivalves are primary or secondary consumers, not apex predators, so they accumulate less Hg through biomagnification than tuna or swordfish. Cardoso 2023 reports tHg in edible bivalves $<0.5 \mu\text{g/g}$ wet weight across three Portuguese estuaries (under the EU 0.5 mg/kg bivalve cap). Rohonczy 2024 Arctic foodweb data shows blue mussel Hg substantially lower than ringed seal Hg in the same Hudson Bay foodweb, consistent with the trophic-level pattern.

So the bivalve-fish differential is Cd-specific. Pb and Hg patterns in bivalves are not similarly amplified.

5 | Structure of the seafood cadmium distribution

The seafood category does not have a single cadmium distribution; it is at least two distributions separated by one-to-two orders of magnitude. Finfish muscle clusters well below the EU 0.05 mg/kg fin-fish cap, while bivalves and cephalopods-without-viscera occupy a distinct, much higher range bounded by the EU 1.0 mg/kg bivalve cap. EU regulatory architecture mirrors this by setting separate per-category cadmium ceilings rather than a single seafood-wide ceiling. Within the bivalve range, the species-level distributions diverge further: scallops and certain oysters sit higher than mussels and clams, so species-resolved characterization carries more information than the pooled bivalve aggregate. The water-column cadmium burden of the source region is an additional documented axis of variation, which is why origin is informative for cadmium when supplier traceability data are available.

6 | What this synthesis does not yet rest on

- **Scallop and oyster-specific evidence is thinner than mussel evidence.** Most of the bivalve corpus in the wiki today is mussel-focused; scallops and oysters have less species-specific characterization. Future ingest should prioritize scallop and oyster-specific surveys for the bivalve sub-category to be evidence-supported beyond extrapolation from mussels.
- **Nanoparticle-bound Cd bioavailability.** Bao 2024 single-particle ICP-MS evidence that some bivalve Cd is in nanoparticle form raises a follow-up question about whether nanoparticle Cd has lower bioavailability than dissolved Cd. If yes, the actual human-relevant exposure may be lower than total-Cd-derived risk models suggest. If no, the existing risk models are accurate. The mechanism is open.
- **Aquaculture vs wild-caught bivalve Cd.** The aquaculture-vs-wild differential well-documented for finfish (aquaculture-vs-wild-contamination-differential) may operate differently in bivalves because farmed bivalves still filter-feed on ambient water (unlike farmed finfish which eat controlled feed). Whether farmed mussels in Cd-managed waters carry meaningfully different Cd than wild mussels in the same region needs separate characterization.

- **Cephalopod viscera consumption patterns.** In some culinary traditions (Mediterranean, East Asian), cephalopod viscera are consumed; the EU "without viscera" caveat does not protect consumers in those contexts, and viscera-inclusive products fall outside the evidence base that the muscle-only cadmium values characterize. Whole-animal or viscera-inclusive cephalopod products therefore require their own cadmium characterization rather than extrapolation from muscle-only data.

7 | Downstream pages updated

- seafood — Levers to reduce contamination section notes bivalve-and-cephalopod water-quality screening as a sourcing lever.
- canned-fish — Source Evidence Inventory cites the bivalve Cd sources where canned-bivalve products (canned mussels, canned clams, canned oysters) are in scope.
- bivalve-molluscs, molluscs, shellfish — Cd contamination profile and ingredient-derivative risk sections should reflect the amplification mechanism.
- cadmium — Toxicology and dietary exposure routes sections should reference bivalves as a high-load source distinct from finfish.

8 | Anchor sources

- bao2024-sp-icp-ms-nps-mussels — Single-particle ICP-MS characterization of Cd in mussels including nanoparticle forms.
- bruno2024-metals-mussels-clams-faro-lake-sicily — Sicilian lagoon mussel/clam Cd survey approaching EU bivalve cap.
- dogruyol2024-mediterranean-mussels-health-risk — Mediterranean mussel multi-metal health-risk model.
- rohoczy2024-arctic-foodweb-cd-hg — Arctic foodweb Cd/Hg evidence showing bivalves at one trophic step.
- cardoso2023-mercury-portuguese-coast-seafood — Portuguese coastal bivalve Cd/Hg survey under EU caps.

9 | How this page was promoted

Established 2026-05-18 from the seafood-axis evidence consolidation. The bivalve-finfish Cd differential has been documented in the literature for decades (the EU's per-category Cd cap differential dates to the original EC 466/2001 framework) but had not been treated as a standalone synthesis on the wiki. The page consolidates that differential and its filter-feeding mechanism into a single literature-native reference.

References

- [1] Risk assessment of toxic residues among some freshwater and marine water fish species
Mohamed A. Hussein, Nanis S. Morsy, Abdallah F. Mahmoud, Wageh S. Darwish, Mohamed T. Elabbasy, František Zigo, et al. · Frontiers in Veterinary Science · 2023 · doi.org/10.3389/fvets.2023.1185395
REVIEW
- [2] Risk-Benefit Assessment of Mercury, Lead, Cadmium, and Arsenic in Inland Fish from Latvian Lakes
Rusko L, Ozola-Davidane R, Kviesis J, and Klavins M · Foods · 2026 · doi.org/10.3390/foods15091516
REVIEW

- [3] Seasonal characterization of mercury contamination along the Portuguese coast: human health and environmental risk assessment
Cardoso PG, Morais H, Crespo D, Tavares D, Pereira E, and Pardal MA · Environmental Science and Pollution Research · 2023 · doi.org/10.1007/s11356-023-29495-5
REVIEW
- [4] Mineral composition in mussel *Mytilus galloprovincialis* and clam *Tapes decussatus* from Faro Lake of Messina: risk assessment for human health
Bruno F, Nava V, Zappalà S, Costa GL, Fazio F, Parrino V, et al. · Frontiers in Toxicology · 2024 · doi.org/10.3389/ftox.2024.1494977
REVIEW
- [5] Evaluation of Health Risks Attributed to Toxic Trace Elements and Selenium in Farmed Mediterranean Mussels from Türkiye and Bulgaria
Dogruyol H, Mol S, Ulusoy S, and Atanasof A · Environmental Science and Pollution Research (published online 1 February 2024) · 2024 · doi.org/10.1007/s12011-024-04084-w
REVIEW
- [6] Single-particle ICP-MS characterisation of metal nanoparticles in mussels
Bao · unknown · 2024 · doi.org/10.1093/jaoacint/qsae024
REVIEW
- [7] Cadmium and mercury trophic transfer in the Arctic marine food web of Hudson Bay
Rohonczy J, Chételat J, Pienkowski L, Goodwin M, Lerash R, Houde M, et al. · Environmental Science and Pollution Research · 2024 · doi.org/10.1007/s11356-024-32268-3
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/-bivalve-cadmium-amplification#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.

PUBLICATION HISTORY

First published 2026-05-18. The full dated record is maintained at <https://heavymetalindex.com/synthesis/-bivalve-cadmium-amplification>.