# Dietary supplements and traditional herbal preparations are a distinct, under-surveilled heavy-metal exposure pathway whose contamination magnitudes reach thousands of times conventional food limits under materially weaker enforcement

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CORRESPONDENCE

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## Abstract

Four independent sources spanning three continents converge on a single structural finding: dietary supplements and traditional herbal preparations are a heavy-metal exposure pathway that behaves unlike the conventional food supply chain in both magnitude and oversight. A peer-reviewed survey of the U.S. retail market, a regulatory comparison across nine pharmacopoeias, and two clinical lead-poisoning case reports from Italy and India together establish that the contamination in this category spans several orders of magnitude, that its upper tail reaches concentrations (tens of thousands of mg/kg lead in a consumed product) that have no analogue anywhere in the conventional food literature, and that the enforcement framework governing it is fragmented, inconsistent across jurisdictions, and in practice weaker than the framework governing foods and pharmaceuticals.

## 1 | Overview

The category is not homogeneous, and the synthesis is careful to separate two mechanistically distinct sub-populations. Western-style botanical extracts such as the Rhodiola rosea capsules surveyed by Porwollik

and Jafari carry contamination in the low hundreds of ppb, consistent with environmental uptake and processing carryover concentrated into a dried extract matrix. Traditional Rasa Shastra Ayurvedic preparations (bhasmas and rasas) documented in the two clinical case reports carry lead and mercury at concentrations four to five orders of magnitude higher, because metals are added to those products intentionally as part of the preparation philosophy. Both sub-populations share the same regulatory blind spot documented by Inada, and both are consumed under a "natural equals safe" assumption that the evidence directly contradicts.

## 2 | The U.S. retail-market signal (Porwollik and Jafari 2026)

[1], published in PLOS ONE (evidence tier A), is the first peer-reviewed investigation of heavy-metal contamination in Rhodiola rosea supplements sold on the U.S. market. Ten products (seven capsular, three tinctures) were purchased from a major online retailer in 2024 and analyzed by ICP-MS at Eurofins Scientific, with limits of quantification of 5 ppb for Cd, Hg, and Pb and 10 ppb for As and Co, all on the supplement matrix as sold. Every one of the seven capsular products contained detectable arsenic, cobalt, and lead; all three tinctures showed no detectable metals.

Total arsenic in the capsular products ranged from 21 to 393 ppb, with the two highest at 393 ppb and 159 ppb. Lead ranged from 9 to 88 ppb. Cadmium was detected in three of seven capsules at 11, 22, and 34.7 ppb. Mercury was detected in only one product, at 10.9 ppb. Cobalt, which is not among the metals typically monitored in food-contaminant panels, reached 733 ppb in a single product. The authors estimated that the most contaminated capsule (a 500 mg serving) contributed approximately 200 ng of arsenic and 360 ng of cobalt per serving. Critically, the arsenic values are total arsenic (tAs); the study did not speciate, and the authors note that inorganic-arsenic speciation would be required to determine whether the two most contaminated products exceed minimal-risk reference levels for iAs. This study establishes that even a mainstream, non-traditional Western botanical, bought from an ordinary retail channel, delivers a measurable and heterogeneous multi-metal load, and that the total-versus-inorganic arsenic ambiguity (the same speciation gap developed in organoarsenical-inertness-assumption) leaves the toxicologically relevant fraction uncharacterized at the point of sale.

## 3 | The regulatory-fragmentation anchor (Inada 2023)

[2], published in the Journal of Natural Medicines (evidence tier A), compares the permitted heavy-metal limits for herbal medicines (Pb, Cd, Hg, As) across nine major pharmacopoeias: the Japanese, European, United States, Chinese, Korean, Taiwanese, Indian, and British pharmacopoeias plus the WHO guidelines. The analysis documents several-fold variation in allowable limits for the same analyte and matrix across these frameworks, with the WHO guidelines serving as a floor that individual jurisdictions either adopt directly or tighten. This source is the enforcement-side anchor of the synthesis. It establishes that there is no single governing standard for metals in herbal products, that a preparation compliant in one jurisdiction can exceed the limit in another by a multiple, and that the "strictest applicable limit governs" only for a brand that actually tests against all of them. Because supplements in most Western markets are regulated as foods rather than as pharmaceuticals, and are not subject to premarket approval, the pharmacopoeial limits Inada compares are frequently aspirational reference values rather than enforced release specifications. The regulatory heterogeneity is not a minor administrative detail; it is the mechanism by which the high-magnitude contamination documented in the other three sources reaches consumers uncaught.

## 4 | The Italian clinical signal (Ciocan et al. 2021)

[3], published in La Medicina del Lavoro (evidence tier B, single clinical case), documents a 30-year-old Indian sailor who presented in Italy with microcytic anemia, abdominal pain, and jaundice after months of oral Ayurvedic medication. Blood lead was 102 µg/dL at an external hospital and 74.61 µg/dL at admission to the authors' occupational-health unit, with urinary lead of 94.7 µg/L; three EDTA chelation cycles brought blood lead down to 36.27 µg/dL at discharge. ICP-MS analysis of four Ayurvedic product samples found lead reaching 23,043 mg/kg and mercury reaching 145,711 mg/kg in the most contaminated preparation, on the product-solid basis as consumed. For scale, the highest reported soil concentrations for the patient's home region of Uttar Pradesh are on the order of 520 mg/kg for lead and 0.49 mg/kg for mercury; the supplement lead was roughly 44 times the worst regional soil, and the supplement mercury roughly 300,000 times, which is dispositive evidence that the metals were added to the product rather than taken up from the environment. Occupational exposure was excluded: three crewmates had normal blood and urinary lead, and more than 150 shipboard products tested lead-free.

This case also supplies the synthesis's most important internal caution about reading concentration as dose. Despite mercury concentrations far exceeding the lead concentrations, the patient showed lead toxicity, not mercury toxicity, consistent with the poor gastrointestinal absorption of the inorganic and sulphide mercury forms used in Rasa Shastra preparations. High measured mercury in a supplement therefore does not translate linearly into absorbed mercury dose, whereas the lead did produce severe, acute, chelation-requiring toxicity. The synthesis treats measured concentration as an upper bound on hazard that must be interpreted through species and absorption, not as a direct dose estimate.

## 5 | The Kerala clinical signal (Thomas et al. 2024)

[4], published in Endocrinology, Diabetes and Metabolism Case Reports (evidence tier B, single clinical case), independently reproduces the Ciocan pattern in a different country, patient, and product. A 58-year-old woman in Kerala presented with fatigue, reduced appetite, and abdominal pain; a peripheral smear showing basophilic stippling and ring sideroblasts prompted heavy-metal testing. Blood lead was 121.20 µg/dL (reference below 25 µg/dL) and random urine lead 400.2 µg/dL (reference below 80 µg/dL). The exposure was an Ayurvedic herbal diabetes capsule purchased over the internet and taken daily for approximately 1.5 months. State drug-analyst testing of the capsule returned a lead content of 40,657 ppm (40,657 mg/kg), against the Ayurvedic Pharmacopoeia of India permissible limit of 10 ppm, an exceedance of roughly 4,066-fold. The patient required dimercaprol (BAL) followed by six weeks of oral d-penicillamine chelation.

Two independent case reports, from different institutions and countries, both finding clinically significant lead poisoning from internet-purchased Ayurvedic capsules containing lead in the tens of thousands of mg/kg, establish that the Ciocan finding is not an isolated anomaly. The upper tail of this product class delivers lead at concentrations that would be inconceivable in any conventional food matrix, where regulatory action limits sit in the low single-digit to low-tens of ppb range (that is, roughly a million-fold lower than 40,657 mg/kg).

## 6 | The mechanistic explanation

The synthesis rests on two distinct mechanisms operating within one commercial category, and conflating them would misstate the risk. The first mechanism is environmental and processing carryover concentrated by extraction. Botanical raw materials take up lead, cadmium, and arsenic from soil, water, and air; drying and extracting the plant into a capsule concentrates the metals from a large mass of raw herb into a small mass of finished powder. This mechanism produces the low-hundreds-of-ppb contamination Porwollik and Jafari measured in Rhodiola, and it is the same mechanism operating in spices (spice-adulteration-lead-infants) and

in the broader botanical supply chain, except that concentration into an extract can push the finished-product value above the raw-herb value.

The second mechanism is intentional metal addition. Rasa Shastra, the Ayurvedic pharmaceutical tradition, deliberately incorporates processed metals and minerals (including lead, mercury, and arsenic compounds) into bhasma and rasa preparations, on the theory that specific calcination and purification steps render them therapeutic. This is not contamination in the quality-control sense; it is a design feature of the product, and it is why the Ciocan and Thomas products carry lead four to five orders of magnitude above what environmental uptake could ever produce, and why the supplement mercury in the Ciocan case exceeded the worst regional soil mercury by roughly five orders of magnitude. No amount of clean sourcing or good agricultural practice addresses this mechanism, because the metal is added on purpose. The only defenses are analytical screening of the finished product and a regulatory framework that requires it.

## 7 | Why conventional surveillance misses this

Conventional food-safety surveillance is built around foods, and supplements are not regulated as foods in the enforcement-relevant sense. In most Western markets a dietary supplement reaches the shelf without premarket approval, without a mandated finished-product heavy-metal specification, and without routine regulatory occurrence monitoring of the kind that underpins total-diet studies for conventional commodities. The Inada comparison shows that even where numeric pharmacopoeial limits exist, they diverge several-fold across jurisdictions and function largely as reference values rather than enforced release gates. Two of the four sources here involve products bought over the internet (the Porwollik Rhodiola sample from a major online retailer, the Thomas diabetes capsule from an online marketplace), a distribution channel that bypasses even the limited retail-level scrutiny that physical supply chains impose.

The result is a category with the same structural profile identified for seaweed in seaweed-cd-as-contamination: high contamination magnitude, low surveillance signal, and a strongly positive consumer perception. The difference is that the supplement pathway adds an intentional-adulteration tail that seaweed does not have, and that the "natural and therefore safe" framing is, if anything, stronger for herbal medicine than for sea vegetables. The two clinical cases both explicitly record the patient's belief that a herbal remedy was safe because it was natural, a false-belief pattern that is itself part of the exposure mechanism. Organic or natural labeling does not address any of this, consistent with organic-certification-not-protective, because neither environmental uptake into an extract nor intentional Rasa Shastra metal addition is constrained by an organic standard.

## 8 | What the evidence implies for testing, regulation, and consumption

For testing, the load-bearing implication is that finished-product analytical screening is not optional for this category, because neither the raw-material provenance nor the label discloses the finished-product metal load. Screening must cover lead, cadmium, total and inorganic arsenic, and both total and (where the product tradition warrants) speciated mercury, because the Porwollik data show a multi-metal signal, the Ciocan data show that total mercury concentration overstates absorbed mercury dose and must be interpreted through species, and the total-versus-inorganic arsenic gap leaves the toxicologically relevant arsenic fraction unresolved when only tAs is measured. Traditional-medicine preparations (TCM, Ayurvedic, and other Rasa Shastra-style products) additionally require screening designed to catch intentional metal addition, not only environmental contamination, because the upper tail there is four to five orders of magnitude higher than an environmental--contamination model would predict.

For regulation, the synthesis supports the position that the fragmentation Inada documents is itself a consumer-protection failure. A category whose upper tail reaches 40,657 mg/kg lead in a consumed product, distributed internationally over the internet under nine divergent and largely unenforced pharmacopoeial regimes, is not adequately governed. Harmonized, enforced, finished-product limits with mandatory testing are the direct implication.

For consumers, the honest quantitative statement is bounded and specific. An adult taking one 500 mg capsule per day of a mainstream Western botanical extract of the kind Porwollik and Jafari surveyed would, at the most contaminated product measured, ingest on the order of 200 ng of total arsenic and 360 ng of cobalt per daily serving, a modest but non-zero and unnecessary addition to background intake, and one that varied more than tenfold across ten products of the same nominal ingredient. At the opposite extreme, an adult taking daily Ayurvedic bhasma or rasa capsules of the kind documented in the two case reports, at lead concentrations of 23,000 to 40,000 mg/kg for roughly six weeks, developed blood lead above 100 µg/dL and clinical lead poisoning requiring chelation. The distance between those two scenarios is the reason this category cannot be characterized by a single qualifier: the pathway spans from a small measurable increment to acute poisoning, and which end a given product occupies is not visible without testing.

## 9 | Uncertainty and what this synthesis does not yet rest on

The synthesis is explicit about its limits. Two of the four anchors are single-patient case reports (evidence tier B) and therefore establish that catastrophic contamination occurs and is clinically real, but they cannot establish its prevalence; they are upper-tail existence proofs, not population estimates. The Porwollik survey is A-tier but small (ten products of a single botanical), so its concentration ranges characterize Rhodiola rosea on the U.S. market rather than the supplement category as a whole. No source in this set provides a large-n, market-representative occurrence distribution for either Western botanical extracts or traditional preparations, which means the synthesis can state magnitude and mechanism with confidence but cannot yet state what fraction of the retail market falls at any given concentration. A market-scale, multi-product occurrence survey, with arsenic speciation and with separate strata for Western extracts and Rasa Shastra preparations, is the study that would convert this from a high-confidence structural finding into a quantified population-exposure estimate, and is a candidate for the Journal of Food Metallomics. The arsenic speciation gap (tAs measured, iAs inferred) is carried forward from organoarsenical-inertness-assumption and is unresolved here for the same reason: none of the four sources speciated arsenic.

This synthesis compounds with combined-exposure-underprotection: a consumer taking multiple supplements, or combining supplements with an already-elevated dietary background, accumulates exposure across products that are each individually unscreened, and the additive burden is exactly the case that single-product, single-analyte thinking misses.

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PEER-REVIEWED

## STATUS AND LICENCE

Editorially reviewed in-house; no external peer review has been completed on this finding. Published as an institutional technical report 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/-supplement-botanical-lead-pathway#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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