HEAVY METAL CERTIFIED · RESEARCH ANALYSIS

Lead and Cadmium in Dark Chocolate: A Decade of Divergence

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Abstract

Dark chocolate and cocoa powder have been under sustained California Proposition 65 enforcement pressure for more than a decade, with private-litigation settlements driving sourcing and processing changes at major manufacturers. Three independent peer-reviewed datasets now bracket the relevant window and permit a direct question: did that pressure move product-level heavy-metal concentrations, and if so, which metals? The answer is metal-specific. Lead in United States dark chocolate declined materially between the 2015 baseline and the early 2020s; cadmium did not, and appears elevated in the organic segment. The divergence is mechanistically explicable rather than coincidental. Lead in cocoa is predominantly processing-side, deposited during drying, transport and manufacturing, and therefore responsive to manufacturer-level intervention. Cadmium is soil-side, taken up from the growing region's geochemistry, and responsive only to sourcing shifts or upstream agronomic mitigation. This analysis reads the three datasets together, sets out the toxicological and regulatory context, and draws the consequence for certification: a standard that reports a single reassuring number, or that leans on the metal which has already improved, misrepresents the residual risk. The honest instrument is finished-product verification against both metals, lot to lot. The underlying evidence and per-source records live on the Heavy Metal Index, the independent literature reference this analysis cites one way.

Chocolate as a natural experiment

Chocolate occupies an unusual position in the food-safety conversation. It is a discretionary pleasure food eaten by nearly everyone, marketed increasingly on health grounds through the high-cocoa dark segment, and derived from a tropical tree crop whose growing regions overlap with some of the most cadmium-rich agricultural soils on the planet. It is also, unlike most of the grocery basket, subject to a functioning subnational enforcement regime. California's Proposition 65 requires a warning for exposures above defined levels, and plaintiff groups have used it for more than a decade to litigate cocoa-product lead and cadmium [4].

That combination makes chocolate a rare natural experiment in food contamination. If a decade of legal and reputational pressure can move contamination in a real, global, commodity supply chain, the effect should be visible in the concentration record. And because the pressure was applied to two metals at once, the experiment carries a built-in control: any difference in how lead and cadmium responded is not an artifact of uneven attention but a signal about the metals themselves. This analysis reads the three United States datasets that bracket the window and asks the question popular coverage rarely answers with data: has the pressure worked, and has it worked equally for both metals?

The scope is deliberately bounded. The finding addresses United States dark chocolate and cocoa powder. Milk chocolate, chocolate-containing infant and toddler foods, and non-United States markets fall outside it and need separate treatment.

The 2015 baseline

The comparator for any trajectory is Abt, Fong Sam, Gray and Posnick Robin (2018), published in Food Additives & Contaminants: Part B [1]. The authors measured lead and cadmium by inductively coupled plasma mass spectrometry in 144 cocoa-product samples — cocoa powder, cocoa nibs, dark chocolate and milk chocolate — drawn from 67 manufacturers and purchased from retail and online channels in December 2015. It is the most-cited United States baseline for chocolate-product lead and cadmium from the mid-2010s, and it predates the first wave of Proposition 65 enforcement settlements against major chocolate manufacturers.

The per-category concentrations, with the percent-cocoa stratification the paper provides, are recorded on the Index source record and are not re-tabulated here. Two features fix the baseline. First, the sampling date pins the "before" point at December 2015. Second, the sampled population — United States retail, 67 manufacturers, several cocoa-product categories — is broad enough to represent a market rather than a boutique sample. This is the distribution against which the later studies are read.

The multi-year trajectory

Hands, Anderson, Cooperman, Balsky and Frame (2024), in Frontiers in Nutrition, reported a multi-year heavy-metal analysis of 72 dark chocolate and cocoa products in the United States market spanning roughly 2014 to 2022 [2]. It is the most comprehensive longitudinal United States chocolate lead-and-cadmium record currently in the corpus, and the load-bearing dataset for the temporal claim.

The headline numbers are sobering in absolute terms. Across the multi-year window, 43 percent of products exceeded the California Proposition 65 Maximum Allowable Dose Level for lead, and 35 percent exceeded the level for cadmium [2]. But the multi-year average conceals a trajectory. The exceedance rate for lead falls across the sampled period, and the timing of that decline aligns with the sequence of major Proposition 65 enforcement settlements affecting United States chocolate manufacturers. The cadmium exceedance rate shows no comparable decline. A separate finding in the same dataset sharpens the asymmetry: organic-certified products carried significantly higher cadmium than conventional products.

An honest reading requires a caveat, and it belongs in the open rather than buried in a limitation paragraph. The paper does not itself attribute the lead decline to Proposition 65 enforcement. That attribution is provisional, resting on the alignment between enforcement timing and the observed trajectory. A definitive causal claim would require a counterfactual — a comparable non-Proposition-65 market measured over the same window — which is not in the corpus. The defensible position is that the temporal decline in lead is real, that its alignment with enforcement timing is suggestive, and that the causal attribution is a hypothesis worth testing rather than an established fact. A certification program is entitled to act on a well-supported hypothesis; it is not entitled to present one as settled.

Why the two metals diverged

The most important part of the finding is not that the two metals behaved differently, but that their divergence was predictable from how each enters the product. Zhao, Wang and Zhao (2024), the most comprehensive multi-matrix toxic-metals review in the corpus, spanning more than 25 food categories across more than 19 countries, supplies the mechanism [3].

Lead in cocoa is predominantly processing-side. It is deposited after harvest — during open-air drying on roadsides and patios, during transport, and during manufacturing — rather than taken up through the plant from soil. Contamination introduced at the post-harvest and manufacturing stages is exactly the kind a regime that pressures manufacturers and finished-product testing can reach. When a settlement compels a company to source cleaner beans, to control drying surfaces, and to test finished lots,

processing-side lead is what falls. The lead trajectory is, in effect, a picture of supply-chain hygiene improving under legal pressure.

Cadmium is soil-side. Cocoa readily takes it up from the ground it grows in, and the highest-cadmium cocoa comes from Latin American producing regions where Andean soil geochemistry, not any processing failure, drives accumulation, with review-level values reaching on the order of 1.8 mg/kg [3]. The Index records the parallel pattern in quinoa, another crop whose cadmium tracks growing-region soil rather than handling. A United States chocolate bar draws from a global bean supply that includes these high-cadmium regions. No amount of manufacturer-stage diligence changes the cadmium a bean already carries out of the field; only shifting sourcing regions, blending to dilute, or intervening agronomically upstream does, and each of those is slower, costlier and less visible than cleaning up a drying yard.

That is the whole asymmetry in a sentence: the two metals enter the chain at different points, so an intervention aimed at the manufacturer moves one and not the other.

Study · Window · Samples · Metals · Key result
Abt et al. 2018 · Dec 2015 · 144 cocoa products, 67 manufacturers · Pb, Cd · United States market baseline, pre-enforcement
Hands et al. 2024 · ~2014-2022 · 72 dark chocolate / cocoa products · Pb, Cd · 43% over Prop 65 Pb level, 35% over Cd level; Pb declining, Cd not; organic Cd higher
Zhao et al. 2024 · Review · 25+ categories, 19+ countries · Multiple · Cocoa Cd up to ~1.8 mg/kg; Pb processing-side, Cd soil-side

What the concentrations mean for health

California's Maximum Allowable Dose Levels are among the most conservative regulatory reference points in use: 0.5 micrograms per day for lead and 4.1 micrograms per day for cadmium, the levels above which a warning is required [4]. They are exposure limits, not concentration limits, so whether a given bar "exceeds" depends on serving size and consumption frequency as well as concentration. This is why a responsible consumer statement specifies dose, population and frequency rather than gesturing at "high" or "safe."

For lead, the toxicological posture of the major bodies is that no exposure is without risk. Both the European Food Safety Authority and the Joint FAO/WHO Expert Committee on Food Additives concluded that a protective threshold intake could not be established, and the latter withdrew its provisional tolerable weekly intake on that basis [5][7]. The population of concern is children, in whom lead is associated with irreversible neurodevelopmental effects at low exposures; the relevant pattern is habitual dark-chocolate or cocoa intake layered on dietary lead from other sources. The cross-source toxicology is compiled on the Index at metals/lead.

For cadmium the concern is chronic rather than acute. The metal accumulates in the kidney across a lifetime, with renal-cortex burden the classic endpoint and a contested but strengthening cardiovascular association in the more recent literature [6]. The European Food Safety Authority set its tolerable weekly intake on the renal endpoint. Because cadmium's harm is cumulative and diet-wide, a persistently higher-cadmium chocolate segment matters less for any single bar than for the lifetime dietary total it contributes to, alongside the shellfish, offal, leafy greens and grains that dominate cadmium intake. The full account is on the Index at metals/cadmium.

The two health stories point in the same practical direction but for different reasons. Lead argues for driving product concentrations as low as the supply chain can be made to deliver, because there is no safe floor. Cadmium argues for the same, because the exposure is cumulative and the chocolate contribution stacks on a diet already carrying it.

The organic paradox

The finding that organic-certified chocolate carried significantly higher cadmium than conventional is counterintuitive and, for many buyers, genuinely surprising, so it deserves a mechanistic explanation rather than a bare statistic. Organic certification governs synthetic inputs; it does not govern the soil-cadmium a plant takes up, and it does not screen growing regions for geogenic cadmium. Some certified-organic cocoa is produced in exactly the high-cadmium Latin American regions described above. A label that certifies the absence of synthetic pesticides carries no information about a soil-borne heavy metal, and can, through sourcing correlation, be associated with more of it.

This is not an indictment of organic production, and it is important not to read it as one. It is a demonstration that a certification aimed at one hazard is silent on an unrelated one. The Index treats the general form of this result — that organic status is not protective against, and is sometimes associated with elevated, heavy-metal load — in its synthesis on organic certification and heavy metals. The lesson for the certification field is structural: seals are answers to specific questions, and a buyer is protected only to the extent the question the seal answers matches the risk the buyer has in mind.

The regulatory landscape

Proposition 65 is the active instrument in this story, but it is not the only frame, and the international picture is moving toward cadmium precisely where United States federal action is thin. Codex Alimentarius adopted maximum levels for cadmium in chocolate in 2018, stratified by cocoa-solids content, giving the international market a harmonized reference the United States federal system lacks for this category [8]. The European Union enforces regulation-level maxima for cadmium in cocoa and chocolate products [11]. The United States Food and Drug Administration's Closer to Zero action plan sets a direction of travel for lead, arsenic, cadmium and mercury in foods for babies and young children, though it does not set chocolate-specific limits for the general market [9].

The through-line is that cadmium in chocolate is increasingly a named regulatory target internationally, while United States federal action on the general-market product remains limited, and it is that gap the California enforcement mechanism has been filling. It is also the gap a private certification standard is positioned to fill more precisely than litigation can, because a standard can set a defined ceiling, apply it uniformly, and verify against it, where enforcement acts case by case and after the fact.

What this means for certification

The certification consequence follows directly from the mechanism, and it is where this analysis earns its keep for the program.

First, a standard must hold both metals to account, and must resist the temptation to lean on the metal that has already improved. Lead is the good-news metal; a program that headlines the lead trajectory while treating cadmium as an afterthought would be technically true and substantively misleading, because cadmium is the residual, harder, still-unmoved risk. The honest posture treats the lead decline as evidence that the category can move when the pathway is tractable, and treats cadmium as the open problem that a credible standard exists to press on.

Second, the two metals demand different verification logics. Lead responds to processing controls, so lead assurance can lean partly on supply-chain and process attestation. Cadmium is carried in the bean; it cannot be inspected or attested away, and it varies by harvest, region and blend. The only reliable instrument for cadmium is measurement of the finished product, lot to lot, against a defined limit — which is precisely the instrument independent testing and certification provide and that a process audit alone does not.

Third, a single reassuring number is the wrong output. Because cadmium tracks sourcing and can drift

bar to bar as blends change, a one-time certificate is weaker than a standing requirement to test each production lot against the ceiling. The design implication is a program built around lot-level finished-product testing rather than a static, point-in-time seal — the difference between certifying that a company once passed and verifying that this box did.

The Heavy Metal Index reports what the literature supports and stops there; setting the ceiling, and deciding how tight it should be relative to the literature floor, is the certification program's job, made openly and labeled for what it is. The gap between what the science strictly requires and what a program certifies to is not a defect to be hidden. It is the mechanism by which a standard pulls a category toward cleaner product over time. Chocolate lead shows the category can be moved; chocolate cadmium shows why the instrument has to keep measuring.

What the evidence does not yet establish

Scholarly honesty about the boundaries of a claim is itself a defensibility asset, so the open edges are stated explicitly. The causal attribution of the lead decline to Proposition 65 enforcement is provisional. The widely cited Consumer Reports dark-chocolate testing program from late 2022 would be a valuable fourth corroborating dataset but is not yet integrated into the Index corpus as a source record; the temporal-decline finding is robust to the three current anchors and would be strengthened by it [10]. Food and Drug Administration Total Diet Study chocolate and cocoa data could add population-level intake context to the product-level concentration picture. And a dedicated timeline of the major enforcement settlements, with dates and affected manufacturers, would move the attribution from suggestive to established. Each is a stated follow-up rather than a quiet assumption.

Conclusion

Read together, the three datasets make a converged claim. Abt 2018 fixes the 2015 United States baseline. Hands 2024 documents the multi-year trajectory and shows lead falling while cadmium holds. Zhao 2024 explains why: lead is processing-side and responsive to manufacturer-level pressure; cadmium is soil-side and responsive only to sourcing or agronomic change upstream. The divergence is mechanistically explicable, not coincidental.

For regulators, the chocolate-lead trajectory is a documented case of state-level enforcement reshaping a national contamination distribution without federal action, when the targeted metal has a tractable, processing-side pathway. For the certification field, the cadmium non-response is the more instructive half: the same pressure does not move every metal equally, because a manufacturer cannot litigate away the geochemistry of a bean's birthplace. A standard that means to protect a buyer has to measure the metal that does not respond to anything short of measurement. Chocolate lead shows the category can be moved. Chocolate cadmium shows why a certification has to keep its instrument in the box.

References

[1] Cadmium and Lead in Cocoa Powder and Chocolate Products in the U.S. Market. E. Abt, J. Fong Sam, P. Gray, and L. Posnick Robin. Food Additives & Contaminants: Part B, 2018. doi: 10.1080/19393210.2017.1420700 (144 cocoa products from 67 manufacturers, sampled December 2015; the pre-enforcement U.S. baseline).

[2] A Multi-Year Heavy Metal Analysis of 72 Dark Chocolate and Cocoa Products in the USA. J. M. Hands, M. L. Anderson, T. Cooperman, J. E. Balsky, and L. A. Frame. Frontiers in Nutrition, 2024. doi: 10.3389/fnut.2024.1366231 (2014–2022; 43% over the Prop 65 lead level, 35% over cadmium; organic higher in cadmium).

[3] Toxic Metals and Metalloids in Food: Current Status, Health Risks, and Mitigation Strategies. D. Zhao, P. Wang, and F. J. Zhao. 2024. doi: 10.1007/s42247-024-00934-6 (multi-matrix review; cocoa cadmium up to ~1.8 mg/kg; lead processing-side, cadmium soil-side).

[4] Proposition 65 Maximum Allowable Dose Levels (MADLs). California Office of Environmental Health Hazard

Assessment (OEHHA). Lead 0.5 µg/day, cadmium 4.1 µg/day — the exposure levels above which a warning is required, among the most conservative regulatory reference points in use.

[5] Evaluation of Lead — Withdrawal of the Provisional Tolerable Weekly Intake. Joint FAO/WHO Expert Committee on Food Additives (JECFA), 2011. Withdrew the provisional tolerable weekly intake for lead on the finding that no protective threshold intake could be established.

[6] Scientific Opinion on Cadmium in Food. European Food Safety Authority (EFSA) CONTAM Panel. EFSA Journal, 2009. Tolerable weekly intake for cadmium set on the renal-cortex endpoint.

[7] Scientific Opinion on Lead in Food. European Food Safety Authority (EFSA) CONTAM Panel. EFSA Journal, 2010. Concluded that no protective threshold intake for lead could be established.

[8] Maximum Levels for Cadmium in Chocolates and Cocoa-Derived Products. Codex Alimentarius Commission, 2018. Cadmium maxima for chocolate stratified by cocoa-solids content (amendment to CXS 193-1995).

[9] Closer to Zero: Action Plan for Baby Foods. United States Food and Drug Administration. Direction of travel for lead, arsenic, cadmium and mercury in foods for babies and young children; no chocolate-specific general-market limit.

[10] Lead and Cadmium in Dark Chocolate. Consumer Reports, 2022. Dark-chocolate testing program. Candidate corpus source, not yet ingested on the Heavy Metal Index.

[11] Maximum Levels for Cadmium in Cocoa and Chocolate Products. European Union. Commission Regulation (EU) 2023/915 (the consolidated contaminants regulation replacing 1881/2006).

[12] Toxicological Profiles for Lead and for Cadmium. Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Department of Health and Human Services.