

Arsenic, Total

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Abstract

Total arsenic (tAs) denotes the sum of inorganic and organic arsenic species in a sample. Organic arsenic species, including arsenobetaine (the principal form in most seafood) and arsenosugars (principal form in seaweed), are substantially less toxic to humans than the inorganic forms. Total arsenic is a meaningful analytical quantity, particularly in contexts where speciation is not performed, but it does not by itself support a health-based interpretation; for that purpose see arsenic, inorganic.

Ufelle & Barchowsky 2021 is attached to this analytical-quantity page only as arsenic-species context. The chapter reinforces why the wiki cannot treat total arsenic as a health-equivalent substitute for inorganic arsenic.

1 | Overview

Total arsenic and inorganic arsenic are different analytes with different toxicological interpretation, and the Heavy Metal Index treats them as non-substitutable per the methodology speciation rule. A total arsenic measurement does not close an inorganic arsenic evidence gap. A regulation written against inorganic arsenic is not satisfied by a total arsenic measurement.

The mechanistic reason is speciation. Arsenic occurs in food as a mixture of inorganic species (arsenite, arsenate) and organic species (methylated forms: monomethylarsonic acid MMA and dimethylarsinic acid DMA; complex organics: arsenobetaine, arsenosugars, arsenolipids). Inorganic arsenic is classified by IARC as a Group 1 carcinogen and is the species of regulatory concern in food. The principal organic forms (arsenobetaine in fin-fish and shellfish, arsenosugars in seaweed and bivalve molluscs) are substantially less toxic and in many cases not reliably bioavailable as inorganic arsenic. A seafood sample with high total arsenic dominated by arsenobetaine carries a fundamentally different risk profile than a rice sample with comparable total arsenic dominated by inorganic species.

The ratio of inorganic to total arsenic varies systematically by matrix. In white rice, inorganic arsenic typically represents the larger share of total arsenic, with brown rice and rice bran carrying higher absolute inorganic

concentrations because the bran layer concentrates the metal. In fin-fish and shellfish, the inorganic share of total arsenic is small (typically a low single-digit percentage), and arsenobetaine dominates. In seaweed, arsenosugars dominate, but inorganic arsenic can also be elevated; the EU sets no binding inorganic-arsenic maximum level for seaweed (arsenic in seaweed is addressed by a monitoring recommendation and the ALARA principle, not a maximum level), though some jurisdictions do set one — Australia/New Zealand at 1 mg/kg and Singapore at 2 mg/kg. Without speciation, the matrix-specific ratio is the only reasoning tool, and the wiki does not generalize a ratio across matrices.

2 | When total arsenic is the analyte of record

Total arsenic is the analyte of record in a substantial subset of the occurrence literature, especially older surveys and resource-constrained sampling programs, because total arsenic by ICP-MS is faster and cheaper than HPLC-ICP-MS speciation. The Heavy Metal Index ingests these sources as total arsenic evidence and does not interpolate inorganic arsenic from them. Where a paper reports both total and speciated arsenic, the speciated values are recorded on the inorganic arsenic page and the total values are recorded here.

For regulatory comparison purposes, total arsenic appears in two contexts. EU Reg. 2023/915 sets a total arsenic maximum level for salt. California Prop 65 anchors arsenic at the speciated inorganic level rather than a total benchmark. FDA and Codex frameworks for food anchor inorganic arsenic, not total. Where source occurrence values are total-only and the applicable regulation is inorganic, the Index records the comparison as not directly possible and flags the speciation gap on the relevant product or ingredient page.

3 | Where total arsenic occurs in food

The matrices with elevated total arsenic, regardless of speciation, are rice and rice products, seaweed and kelp products, seafood (especially fin-fish and bivalve molluscs), and to a lesser degree poultry and game meats. Drinking water can also carry elevated total arsenic in regions with arsenic-rich aquifers, with the species predominantly inorganic.

For per-commodity occurrence detail see rice, seaweed, fish, seafood, and shellfish. For regulatory limits applying to inorganic arsenic in rice, seaweed, and rice-based beverages see EU Reg. 2023/915. For the FDA action level for inorganic arsenic in infant rice cereal see FDA Closer to Zero — iAs in infant rice cereal.

4 | How the index records total versus inorganic arsenic

The Heavy Metal Index records the two analytes separately throughout. Source pages declaring metals: [tAs] route to this page; source pages declaring metals: [iAs] route to the inorganic arsenic page. Source pages declaring both route to both. The ingredient contamination_profile schema carries a separate tAs sub-block, allowing the wiki to record the total-arsenic literature for a commodity even where the iAs literature is thin. Total arsenic measurements cannot substitute for inorganic arsenic where the applicable regulatory limit is anchored to the inorganic species; closing that gap requires iAs-speciated values or a documented matrix-specific inorganic share applied to the total measurement.

5 | Testing

Total arsenic by ICP-MS is the dominant occurrence-survey method. Arsenic speciation is performed by HPLC-ICP-MS with anion-exchange chromatography for inorganic arsenic, MMA, and DMA, or by cation-exchange for arsenobetaine and arsenocholine. See [icp-ms](#) and [arsenic-speciation](#) for analytical detail.

6 | Frequently asked questions

What is total arsenic, and how is it different from inorganic arsenic?

Total arsenic (tAs) is the sum of all inorganic and organic arsenic species in a sample. The organic forms, such as arsenobetaine (the main form in most seafood) and arsenosugars (the main form in seaweed), are substantially less toxic to humans than the inorganic forms. Inorganic arsenic is classified by IARC as a Group 1 carcinogen and is the species of regulatory concern in food, so total arsenic on its own does not support a health-based interpretation.

Which foods tend to have elevated total arsenic?

The matrices with elevated total arsenic are rice and rice products, seaweed and kelp products, and seafood, especially fin-fish and bivalve molluscs, and to a lesser degree poultry and game meats. Drinking water can also carry elevated total arsenic in regions with arsenic-rich aquifers, where the arsenic is predominantly inorganic. See [rice](#), [seaweed](#), [fish](#), [seafood](#), and [shellfish](#) for per-commodity detail.

Does a high total arsenic reading in seafood mean the food is dangerous?

Not necessarily, because the toxicity depends on which arsenic species dominate. In fin-fish and shellfish the inorganic share of total arsenic is small, typically a low single-digit percentage, and the much less toxic arsenobetaine dominates. A seafood sample with high total arsenic dominated by arsenobetaine carries a fundamentally different risk profile than a rice sample with comparable total arsenic dominated by inorganic species.

Are there legal limits set for total arsenic in food?

Total arsenic appears in regulation in limited contexts. EU Reg. 2023/915 sets a total arsenic maximum level for salt, while most food frameworks anchor to inorganic arsenic instead: California Prop 65, FDA, and Codex all anchor arsenic at the inorganic level rather than a total benchmark. EU Reg. 2023/915 also sets a specific inorganic-arsenic maximum level for seaweed, and there is an FDA action level for inorganic arsenic in infant rice cereal (FDA Closer to Zero — iAs in infant rice cereal).

How is arsenic measured, and why can't a total arsenic result be compared directly to arsenic limits?

Total arsenic by ICP-MS is the dominant occurrence-survey method because it is faster and cheaper than speciation, while arsenic speciation is performed by HPLC-ICP-MS to separate inorganic arsenic, MMA, DMA, and arsenobetaine (see [icp-ms](#) and [arsenic-speciation](#)). A total arsenic measurement cannot satisfy a regulation written against inorganic arsenic, because the two are different analytes with different toxicological interpretation and the inorganic-to-total ratio varies systematically by matrix.

Why does the inorganic share of total arsenic vary between rice and seafood?

The ratio of inorganic to total arsenic varies systematically by matrix. In white rice, inorganic arsenic typically represents the larger share of total arsenic, with brown rice and rice bran carrying higher absolute inorganic concentrations because the bran layer concentrates the metal. In fin-fish and shellfish the inorganic share is small and arsenobetaine dominates, while in seaweed arsenosugars dominate although inorganic arsenic can also be elevated. Without speciation, this matrix-specific ratio is the only reasoning tool, and it is not generalized across matrices.

References

- [1] Toxic Effects of Metals (Chapter 23), in Casarett & Doull's Essentials of Toxicology, Fourth Edition
Ufelle AC and Barchowsky A · Casarett & Doull's Essentials of Toxicology, Fourth Edition. McGraw Hill Education · 2021 · www.mhprofessional.com
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