Cesium

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Abstract

Cesium in food: radioactive isotopes from nuclear accidents concentrate in shiitake mushrooms and game meat; stable cesium toxicology remains poorly characterized in the available sources.

1 | Isotopes and food safety context

Cesium (Cs) exists in both stable and radioactive forms, and the distinction matters for food safety interpretation. Stable cesium-133 (133Cs) is the only naturally occurring cesium isotope. It is present in soil, water, and vegetation at trace levels arising from geochemical processes, is taken up by plants through the same pathways as potassium (a chemically analogous element), and transfers to food crops and livestock at low concentrations. Radioactive cesium isotopes, primarily cesium-134 (134Cs, half-life 2.06 years) and cesium-137 (137Cs, half-life 30.1 years), are fission products released during nuclear events and are not naturally present at significant levels. Post-accident environmental contamination with these isotopes becomes the dominant food safety concern for cesium in affected regions.

The evidence supporting this page draws on three peer-reviewed studies, all from Japan and all arising from the context of the March 2011 Fukushima Daiichi nuclear power plant accident. Koizumi et al. 2012 surveyed radioactive cesium in dietary meals, milk, and vegetables approximately four months after the accident. O'Brien et al. 2019 characterized stable cesium transfer factors from oak logs to shiitake mushrooms. Saito et al. 2022 reported 137Cs in wild boar muscle from the Fukushima difficult-to-return zone across a five-year monitoring period. The existing toxicological listing from Ufelle and Barchowsky 2021 places cesium among minor toxic metals without a detailed subsection.

2 | Toxicology

The available sources do not characterize a dose-response relationship for stable cesium chemical toxicity. Ufelle and Barchowsky 2021 list cesium among minor toxic metals in the Essentials of Toxicology chapter on toxic effects of metals, without a dedicated cesium subsection and without a reference value.

The radioactive isotopes 134Cs and 137Cs present a radiological rather than a chemical toxicological hazard. Because cesium behaves similarly to potassium, ingested radiocesium distributes broadly to soft tissues and muscles rather than localizing to a single target organ. Effective dose coefficients for ingested radiocesium, as published by the International Commission on Radiological Protection (ICRP Publication 72) and cited by Koizumi et al. 2012, are 0.019 µSv/Bq for 134Cs and 0.013 µSv/Bq for 137Cs. For inhalation, the corresponding coefficients are 0.02 µSv/Bq for 134Cs and 0.039 µSv/Bq for 137Cs.

Radiological health risk from dietary cesium depends on cumulative effective dose. Koizumi et al. 2012 estimated that the maximum combined inhalation and ingestion dose in areas outside the 20-km evacuation radius around the Fukushima plant, in July 2011, was approximately 160 µSv/year (83.1 µSv/year by ingestion and 76.9 µSv/year by inhalation). That figure was well below the publicly permissible dose of 1 mSv/year recognized by the Japanese Ministry of Health, Labour and Welfare.

3 | Typical exposure routes

For the general population in uncontaminated regions, stable cesium enters the food supply through soil-to-plant uptake. Cesium is taken up by roots because of its chemical similarity to potassium, and it transfers from soil to crops and from crops to livestock at low concentrations that reflect ambient geochemical levels.

After a nuclear accident, the dominant additional exposure routes are dietary ingestion of contaminated foods and inhalation of resuspended deposited activity. Koizumi et al. 2012 measured both routes in Fukushima Prefecture in July 2011. Inhalation doses at most sampled sites outside the 20-km evacuation zone were below 3 µSv/year for 134Cs and 137Cs combined, but reached 76.9 µSv/year at Namie town and 27.7 µSv/year at Katsurao village, both near the edge of the evacuation zone. Approximately 74% of total 134Cs and 81% of total 137Cs in sampled air were in the respirable fraction (aerodynamic diameter below 4.9 µm) (Koizumi et al. 2012, Table 3).

For mushroom cultivation, cesium in the wood substrate transfers to fruiting bodies at a substantial ratio. O'Brien et al. 2019 found that the log-to-shiitake transfer factor for stable cesium (133Cs) was 23 to 29 on a dry weight basis (sawdust TF: mean 23 plus or minus 4.0; heartwood TF: mean 29 plus or minus 6.9; sapwood TF: mean 27 plus or minus 3.3), far higher than the radiocesium (137Cs) TF of approximately 0.43 reported in prior literature from the first year after the accident. The authors attribute the difference to the fact that at the time of post-accident measurement, 137Cs was concentrated in bark (the most recently contaminated compartment), whereas 133Cs is distributed throughout the wood.

Wild game, including wild boar, can accumulate radioactive cesium from contaminated food resources including roots, berries, herbs, and mushrooms. Saito et al. 2022 found that wild boar in the Fukushima difficult-to-return zone showed no significant decline in 137Cs muscle activity over five years of monitoring, suggesting ongoing dietary uptake from the contaminated environment rather than declining contamination with time.

4 | Food sources

Among the food matrices surveyed post-Fukushima, shiitake mushrooms showed the highest contamination relative to other vegetables. Koizumi et al. 2012 found that no vegetable exceeded 100 Bq/kg for total radioactive cesium (134Cs plus 137Cs) except shiitake mushrooms. In Kawamata, shiitake total activity reached 304.6 Bq/kg (140.4 Bq/kg 134Cs plus 164.2 Bq/kg 137Cs); in Minamisouma, 281.8 Bq/kg. These values represented up to 60% of the then-current 500 Bq/kg vegetable limit. Shiitake at Iwaki (farther south) were not detectable. The spatial gradient reflected prevailing wind direction from the plant (Table 2). Radioactivities in other surveyed vegetables

generally fell below 25 Bq/kg, with notable exceptions: New Zealand spinach at Date (62.6 Bq/kg) and cherry fruits at Souma (66.6 Bq/kg) and Nihonmatsu (52.9 Bq/kg).

Cow's milk sampled from Fukushima Prefecture had a median total activity of 4.1 Bq/kg (range: not detectable to 10.1 Bq/kg), one order of magnitude below the then-current 200 Bq/kg limit (Koizumi et al. 2012, Table 2). All 21 milk samples collected across four sampling sites remained below the limit.

For whole-day dietary meal sets, 36 of 55 (65.5%) from Fukushima Prefecture exceeded the method detection limit for either 134Cs or 137Cs. The median estimated ingestion dose was 3.0 µSv/year (range: not detectable to 83.1 µSv/year), with the highest mean dose in Souma (17.4 plus or minus 25.3 µSv/year) (Koizumi et al. 2012, Table 1).

For game meat, wild boar muscle from the Fukushima difficult-to-return zone exceeded the 100 Bq/kg fresh mass standard in all 221 samples measured between 2016 and 2020. Annual mean concentrations ranged from 3,030 Bq/kg fresh mass in 2017 to 15,028 Bq/kg fresh mass in 2016, with individual maxima reaching 132,210 Bq/kg fresh mass in 2016 (Saito et al. 2022, Table 1). These levels are orders of magnitude above the consumption standard.

The stable cesium concentrations in shiitake fruiting bodies under non-accident cultivation conditions (Tochigi Prefecture) were 591 plus or minus 319.3 µg/kg dry weight (range across logs: 258 to 1255 µg/kg dry weight) (O'Brien et al. 2019, Table 1). These values reflect ambient geochemical stable cesium and do not represent a food safety concern under non-accident conditions; they are cited here as context for the transfer factor findings.

MATRIX	MEASURE	VALUE	SOURCE
Shiitake (Kawamata, Fukushima, 2011)	Total radioactive cesium	304.6 Bq/kg fresh weight	Koizumi 2012
Shiitake (Minamisouma, Fukushima, 2011)	Total radioactive cesium	281.8 Bq/kg fresh weight	Koizumi 2012
Cow's milk (Fukushima, 2011)	Median total radioactive cesium	4.1 Bq/kg	Koizumi 2012
Wild boar muscle (Fukushima DRZ, 2016)	Annual mean 137Cs	15,028 Bq/kg fresh mass	Saito 2022
Wild boar muscle (Fukushima DRZ, 2020)	Annual mean 137Cs	3,568 Bq/kg fresh mass	Saito 2022
Shiitake fruiting bodies (Tochigi, 2018)	Stable 133Cs, mean	591 µg/kg dry weight	O'Brien 2019

5 | Regulatory limits

The limits cited by the sources in this page were established by the Japanese Ministry of Health, Labour and Welfare in response to the 2011 Fukushima accident. These are limits on total radioactive cesium (134Cs plus 137Cs combined activity), not limits on stable cesium content in food.

Koizumi et al. 2012 (data from July 2011) report the limits then in effect: 200 Bq/kg for cow's milk and 500 Bq/kg for vegetables and fruits. Saito et al. 2022 (data from 2016 to 2020) reference a standard of 100 Bq/kg fresh mass for game meat consumed from the region.

No stable cesium food safety limits, tolerable intake values, or regulatory maximum levels are reported by any of the sources on this page. The absence of such limits in the available evidence reflects the low acute and chronic toxicity attributed to stable cesium at dietary concentrations, though formal dose-response characterization is not available from the sources cited here.

6 | Testing

Radioactive cesium isotopes (134Cs, 137Cs) are measured by gamma spectrometry, typically using high-purity germanium (HPGe) detectors. Characteristic gamma energies are 134Cs at 604.7 keV and 795.9 keV, and 137Cs at 661.7 keV (Koizumi et al. 2012). Saito et al. 2022 used a germanium semiconductor detector (Canberra GC3018) on freeze-dried, crushed muscle tissue, with gamma measurements counted for 48 hours.

Stable cesium (133Cs) is measured by inductively coupled plasma mass spectrometry (ICP-MS). O'Brien et al. 2019 used a PerkinElmer NexION 350S ICP-MS with a cesium external standard (998 mg/L) and indium internal standard; average precision for 133Cs was 8.5%. Samples were acid-digested (10 mL HNO3, 60 to 61% mass/mass) in a microwave digestion system before ICP-MS analysis.

Radioactive and stable cesium require different analytical approaches and report on different hazard contexts. A gamma-spectrometry result for radioactive cesium (Bq/kg) is not comparable to an ICP-MS total cesium concentration (µg/kg) without isotope-specific conversion.

7 | Microbiome effects

No evidence on cesium effects on the gut microbiome was identified in the sources on this page. This section remains a gap.

8 | Vulnerable populations

The sources on this page do not characterize differential sensitivity to cesium by age or population group. The general principle that children receive a larger dose per unit body weight for a given ingested activity applies to radioactive cesium as it does to other radionuclides, but no pediatric-specific dose estimates appear in the sources reviewed here.

Residents in heavily contaminated zones, including hunters and foragers who consume locally sourced game meat or wild mushrooms from restricted areas, receive higher exposures than the general population. Saito et al. 2022 document that 137Cs concentrations in wild boar from the Fukushima difficult-to-return zone exceeded the 100 Bq/kg consumption standard by factors of tens to thousands in all 221 animals sampled across five years, indicating that consumption of this matrix from restricted zones would result in substantially higher cesium intake than from commercially available sources.

9 | Mitigation

The sources in this page do not describe decontamination or mitigation strategies for cesium in food. The monitoring data from Saito et al. 2022 indicate that environmental cesium contamination in the Fukushima

difficult-to-return zone persisted at high levels across five years of observation, suggesting that passive environmental decay of 137Cs (physical half-life 30.1 years) is insufficient to bring concentrations below regulatory thresholds on a consumer-relevant timescale. Access restrictions on the highest-contamination zones are the primary documented mitigation measure in the sources reviewed here.

For mushroom cultivation from cesium-contaminated logs, O'Brien et al. 2019 describe the methodological context for sampling cesium transfer from wood to shiitake, including a provisional 50 Bq/kg fresh weight limit set by Japan for radiocesium in logs (100 Bq/kg fresh weight of logs divided by the transfer factor of 2). The transfer factor findings suggest that log cesium content is predictive of fruiting body cesium and can be used to assess pre-harvest risk.

10 | What remains uncertain

The long-term trajectory of 137Cs in Fukushima difficult-to-return zone wildlife beyond the five-year monitoring period of Saito et al. 2022 is not established. The effective ecological half-life observed (3.0 to 5.5 years) reflects a combination of physical decay and biological dynamics; whether this rate continues or changes as environmental pools deplete is unknown from the sources available here.

Stable cesium chemical toxicology at dietary concentrations is not characterized by any source on this page. Ufelle and Barchowsky 2021 list cesium among minor toxic metals without a dose-response estimate, and no reference value for stable cesium intake is derived from the available evidence.

The spatial extent of elevated food-chain cesium contamination outside the formally designated difficult-to-return and evacuation zones is not fully characterized by the studies available here, all of which focus on clearly demarcated high-contamination areas in Fukushima Prefecture.

The behavior of cesium in later crop cycles for shiitake mushrooms grown on contaminated logs is not addressed by O'Brien et al. 2019, which measured only first-crop fruiting bodies.

11 | Frequently asked questions

Is cesium a toxic metal?

Cesium is listed among minor toxic metals for which toxicity has been described, per Ufelle & Barchowsky 2021. Beyond that listing, the page does not yet describe specific cesium toxicity, because the source chapter does not provide a detailed cesium subsection.

Does this page tell me how much cesium is in food or how I might be exposed?

No. This page is currently a source-map stub and does not cover dietary sources, exposure routes, or contamination levels for cesium. Substantive cesium-specific content awaits a dedicated ingest.

Why is there so little information on this cesium page?

The page was created as source-map context during the re-ingest of Ufelle & Barchowsky 2021, which lists cesium but does not include a detailed cesium subsection. As a result the page is explicitly marked a stub, and fuller expansion is pending a dedicated ingest.

What source does the cesium information come from?

The single source cited is Ufelle & Barchowsky 2021, the "Toxic Effects of Metals" chapter (Ch 23) in Casarett & Doull's Essentials of Toxicology, 4th edition. It is the only reference currently underpinning this page.

References

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PEER-REVIEWED

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PEER-REVIEWED

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TEXTBOOK

STATUS AND LICENCE

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DATA AVAILABILITY

Every source behind this reference is listed with its own source record at https://heavymetalindex.com/metals/cesium#sources.

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