Mercury Contamination in Fish Oil Supplements (2019–2024): A Multi-Region Assessment

Fish oil supplements derived from aquatic organisms are among the most popular dietary supplements worldwide, valued for their rich content of omega-3 polyunsaturated fatty acids (EPA and DHA). However, these supplements present a significant challenge to regulatory agencies and public health authorities: they may concentrate mercury and other toxic contaminants from their source materials.

Executive Summary

This narrative literature review examines evidence on mercury contamination levels in commercial fish oil supplements, regulatory standards across major jurisdictions, regional variation patterns, and health implications for vulnerable populations. The review synthesizes data from systematic monitoring studies, regulatory assessments, and clinical investigations published between January 2019 and December 2025, including searches of PubMed, ScienceDirect, and regulatory repositories from the FDA, Health Canada, EFSA, MHLW, and Codex/WHO.

Contamination Sources

Mercury enters aquatic ecosystems through industrial activities and bioaccumulates in fish used for supplement production

Regulatory Standards

Maximum allowable mercury levels vary considerably across major jurisdictions worldwide

Health Implications

Vulnerable populations including pregnant women and children face particular risks from mercury exposure

Sources and Pathways of Mercury in Fish Oil Products

Mercury is a naturally occurring toxic element that enters aquatic ecosystems through both natural geological processes and anthropogenic sources. Industrial activities including coal combustion, artisanal and small-scale gold mining, waste combustion, cement production, and non-ferrous metals smelting are major contributors to atmospheric mercury emissions, which are subsequently deposited in marine and freshwater environments. Once in aquatic systems, inorganic mercury undergoes microbial methylation to form methylmercury, the highly toxic organic form that preferentially bioaccumulates in aquatic organisms [1].

Fish and marine organisms accumulate methylmercury through dietary exposure and water uptake, with concentrations increasing through trophic transfer. Large predatory fish and long-lived fish species demonstrate particularly high mercury burdens due to their position in food webs and extended lifespan [1]. When fish oils are extracted and concentrated for dietary supplement production, mercury concentrations can increase relative to the original fish tissue because mercury is incorporated into the lipid fraction alongside the beneficial omega-3 fatty acids [2].

> The chemistry of methylmercury makes it particularly problematic: it readily penetrates biological membranes, crosses the blood-brain barrier, and accumulates in neural tissue where it causes neurotoxicity [1].

This chemical behavior has made methylmercury exposure a persistent public health concern, particularly in populations with high seafood consumption patterns, both through direct fish consumption and through supplementation.

Global Fishing Patterns and Mercury Extraction from Oceans

Global fishing practices significantly influence human exposure to methylmercury through seafood and supplements. Compounding contamination issues, seafood harvested from specific regions may contain lower levels of protective micronutrients such as selenium and omega-3 fatty acids compared to fish from other waters, further complicating the risk-benefit calculation for consumers. Industrial fisheries targeting large pelagic species have thus become a significant source of potential mercury exposure for supplement consumers. This geographic pattern has critical implications for supplement sourcing: fish oil products derived from certain fishing regions may carry higher mercury burdens than those from other areas [1].

01

Mercury Emission

Industrial activities release mercury into atmosphere

02

Aquatic Deposition

Mercury deposits in marine and freshwater environments

03

Microbial Methylation

Inorganic mercury converts to toxic methylmercury

04

Bioaccumulation

Fish accumulate methylmercury through food web

05

Supplement Production

Mercury concentrates in extracted fish oil products

International and Regional Regulatory Standards

Regulatory agencies across major jurisdictions have established maximum allowable mercury levels for dietary supplements and food products, though standards vary considerably. The European Commission Regulation (EC) No. 629/2008 and the International Council for Harmonisation (ICH) Q3D guidelines specify permissible mercury levels in food, dietary supplements, and medicinal products [1]. Notably, regulatory standards for dietary supplements are typically more stringent than those for fish meat products, reflecting the concentrated nature of supplement preparations and the lack of consumption volume limitations.

The FDA in the United States, the European Food Safety Authority (EFSA), Health Canada, Japan's MHLW, and the Codex Alimentarius Commission/WHO establish acceptable mercury thresholds based on tolerable daily intakes (TDIs) and maximum residue limits (MRLs). For example, regulatory bodies classify mercury as a priority hazardous substance and typically set action levels differentiated by food category and vulnerable populations such as children. However, the heterogeneity of regulatory approaches across regions creates challenges for manufacturers and consumers. While European standards for supplements may require mercury levels below 0.10 mg/kg, other jurisdictions may employ different thresholds or rely on risk-based assessments that consider typical consumption patterns and demographic factors [1].

United States (FDA)

Post-market surveillance approach with action levels based on tolerable daily intakes

European Union (EFSA)

Pre-market safety dossiers required, mercury limits below 0.10 mg/kg for supplements

Canada (Health Canada)

Stringent pre-market scrutiny with quality documentation requirements

Quality Control and Mandatory Testing Requirements

A critical gap in supplement regulation across many jurisdictions is the lack of mandatory pre-market quality control testing. Unlike pharmaceutical products, dietary supplements in many countries, particularly the United States and Canada, do not require manufacturer demonstration of safety or quality before being placed on market shelves [1]. This regulatory gap has significant implications: manufacturers may lack incentive to rigorously test their products, and contaminated supplements may enter commerce without detection until post-market surveillance identifies problems.

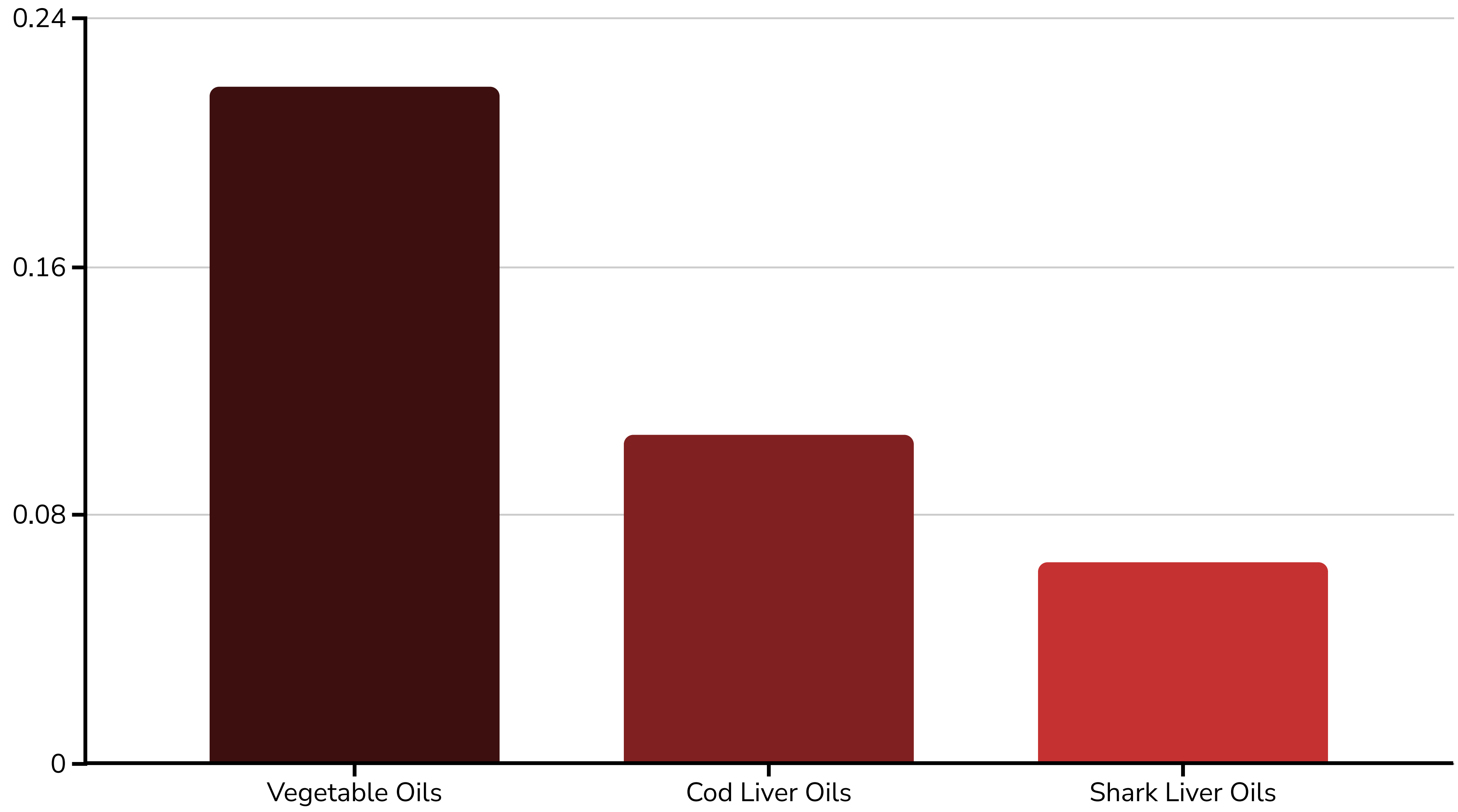
> **Regulatory Gap:** The lack of mandatory pre-market testing means contaminated supplements may reach consumers before problems are detected through post-market surveillance.

Health Canada and regulatory authorities in European Union member states impose more stringent pre-market scrutiny, with requirements for quality documentation and sometimes testing by third-party laboratories. The EFSA requires safety dossiers for novel foods and supplements, which may include mercury analysis for fish oil products, particularly those marketed for vulnerable populations such as pregnant women or children [1]. In contrast, the FDA's dietary supplement framework relies primarily on post-market reporting of adverse events rather than pre-market approval, creating opportunity for contaminated products to persist in commerce.

European Studies: Poland and Central Europe

Poland provides a particularly well-documented example of regional mercury monitoring in fish oil supplements. A comprehensive 2023 analysis examined mercury content in 36 dietary supplements available on the Polish market, including cod liver oils, shark liver oils, and vegetable oils [3]. The study employed atomic absorption spectrometry with amalgamation technique to determine mercury concentrations across the product range.

Among the tested Polish market supplements, mercury concentration ranged from 0.023 to 0.427 μg/kg, with an average of 0.165 μg/kg [3]. Significant differences emerged between supplement types: vegetable oils contained the highest average mercury concentration (0.218 μg/kg), more than twice that of cod liver oils (0.106 μg/kg) and shark liver oils (0.065 μg/kg). However, critically, none of the tested supplements exceeded the acceptable standard for dietary supplements (0.10 mg/kg), leading researchers to conclude that mercury content in Polish market products was at a low level, guaranteeing safety of use.



More recently, a 2025 analysis provided updated assessment of mercury in fish oil supplements within the context of omega-3/omega-6 supplementation [1]. This analysis confirmed that commercially available fish oil supplements typically contain mercury in amounts below established limits, making them safe for consumption under normal usage. However, the authors emphasized that the dynamic development of the supplement market and the lack of mandatory quality control before products reach consumers necessitates constant monitoring and potential tightening of legal requirements.

Across Europe more broadly, studies in the UAE market provide additional insights into geographic variation in mercury contamination. An analysis of 200 health supplement products sold in Dubai found that 99% of mercury content was below the limit of detection of the analytical method employed. Using single imputation methods to account for values below limit of detection, the estimated average daily mercury intake from supplements was 0.09 μg, compared to the tolerable daily intake of 20 μg, indicating that with proper use per manufacturer instructions, supplement consumption would not exceed safe mercury exposure thresholds.

Marine Biomonitoring: Evidence from Fish and Organisms

Regional patterns of mercury contamination in wild and farmed aquatic organisms provide context for understanding mercury sources for supplement production. Long-term monitoring programs in the Baltic Sea have documented mercury in fish species used for oil extraction and human consumption. The Swedish National Monitoring Programme for Contaminants in Marine Biota (MCoM), maintained since 1978, provides decades of contaminant data including mercury in Atlantic herring, Atlantic cod, European perch, and other fish species [4]. These datasets reveal temporal trends and spatial hotspots of mercury contamination that reflect industrial emissions, coastal pollution patterns, and food web dynamics.

In tropical regions where much global fishing for fish oil production occurs, mercury concentrations in marine organisms vary substantially by location and species. Assessment of fish from Callao Bay, Peru, demonstrated that mercury and lead concentrations in certain fish species exceeded international standards, highlighting contamination in major fishing regions [5]. Similarly, analysis of Yuhuan coastal area in China revealed mercury as the dominant contributor to regional ecological risk. These findings suggest that even in areas meeting regulatory standards, mercury is a significant contaminant warranting careful monitoring of seafood and supplements derived from those regions.

Baltic Sea Region

Swedish monitoring since 1978 tracks mercury in Atlantic herring, cod, and perch used for supplement production

Tropical Fishing Regions

Callao Bay, Peru shows mercury and lead exceeding international standards in certain fish species

Asian Coastal Areas

Yuhuan coastal area in China identifies mercury as dominant contributor to ecological risk

Analytical Methods for Mercury Detection in Supplements

Accurate determination of mercury in fish oil supplements requires validated analytical methodology. The most commonly employed techniques for trace metal analysis include atomic absorption spectrometry (AAS), inductively coupled plasma optical emission spectrometry (ICP-OES), and inductively coupled plasma mass spectrometry (ICP-MS). These methods offer varying sensitivity, specificity, and cost profiles, influencing their adoption by manufacturers and regulatory laboratories.

More recent analytical advances have enabled rapid, non-destructive assessment of fish oil supplement quality. Fourier transform infrared (FTIR) spectroscopy combined with partial least squares regression can quantify EPA and DHA content while also providing information about oxidative status [8]. Benchtop nuclear magnetic resonance (NMR) can differentiate fatty acid forms (triacylglycerols versus ethyl esters) and identify partial glycerides and unexpected compounds [7], though these methods primarily assess nutritional rather than toxicological quality.

Atomic Absorption Spectrometry (AAS)

Traditional method for trace metal analysis with established protocols and moderate sensitivity

ICP-OES and ICP-MS

Advanced techniques offering high sensitivity and specificity for mercury detection

FTIR Spectroscopy

Rapid, non-destructive assessment of EPA/DHA content and oxidative status

Nuclear Magnetic Resonance

Differentiates fatty acid forms and identifies unexpected compounds in supplements

Contamination Patterns Across Supplement Categories

Fish oil supplements encompass diverse product formulations derived from varied source materials, and mercury contamination patterns differ among these categories. The most direct sources—cod liver oils and shark liver oils—contain both beneficial omega-3 fatty acids and potential mercury contamination. Cod liver oils from Atlantic and Pacific cod fishing grounds typically contain lower mercury levels than oils derived from tropical or subtropical species, reflecting the trophic position and biogeography of these species [1].

Shark liver oils present particular concern because sharks occupy a higher trophic position than most fish species, resulting in greater methylmercury bioaccumulation [1]. However, when shark liver oils are properly sourced from low-mercury regions and processed to minimize environmental contaminants, they can meet regulatory standards [3]. Antarctic krill oil, a relatively newer supplement category, was found in comparative analysis to contain intermediate levels of persistent organic pollutants when compared to various fish oil categories, with EPA and DHA content adhering closely to manufacturer specifications [9].

Alternative omega-3 sources from microalgae present a potential avenue for reducing mercury contamination risk. Microalgal oils can provide concentrated EPA and DHA without the mercury bioaccumulation inherent to fish oil production [10]. Studies examining microalgae-based products detected high frequencies of other heavy metals (83–100% of products) including arsenic and cadmium, but the mercury contamination patterns differed from fish oils, suggesting that source material selection significantly influences contamination profiles [11].

Cod Liver Oils

Lower mercury levels from Atlantic and Pacific fishing grounds

Shark Liver Oils

Higher trophic position leads to greater bioaccumulation concerns

Antarctic Krill Oil

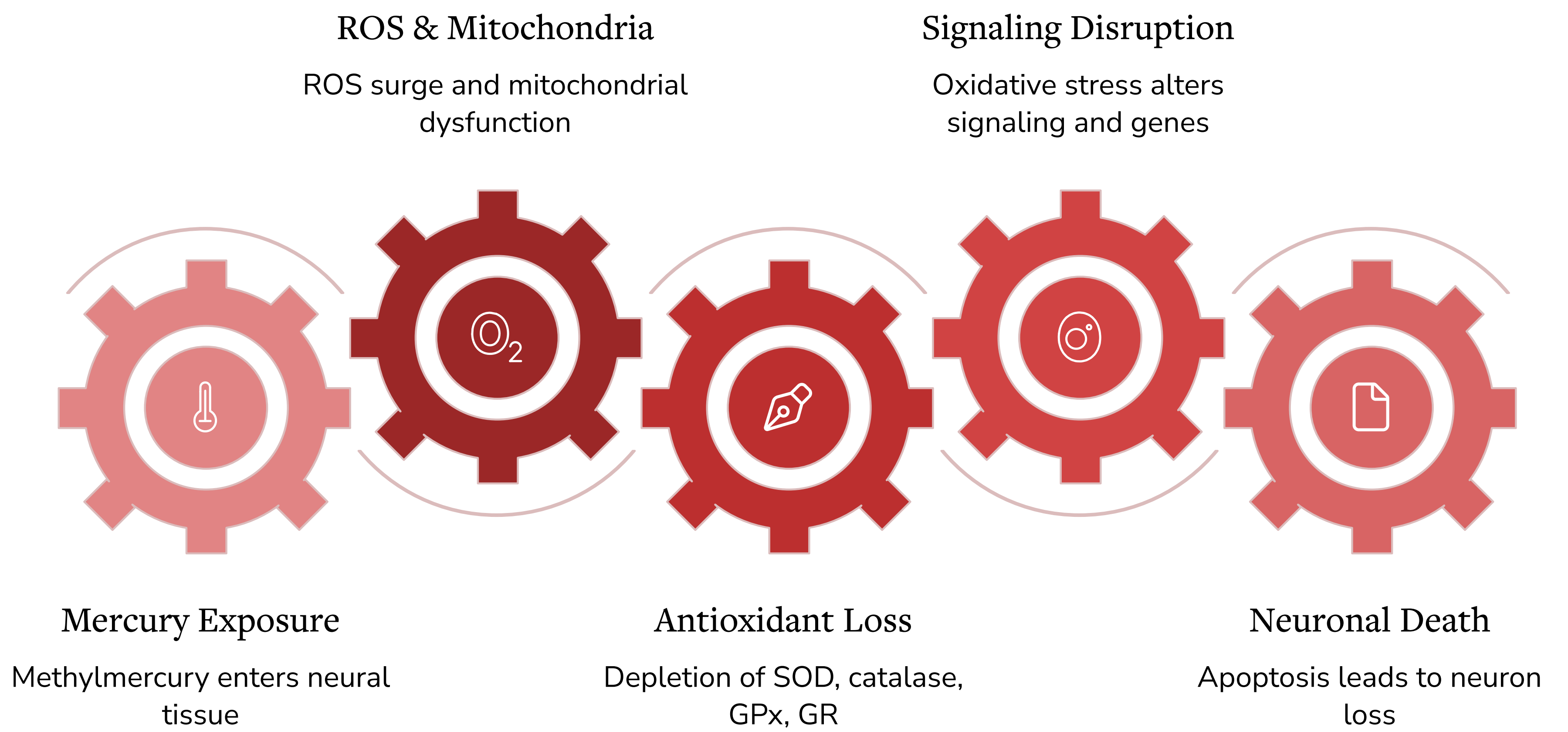
Intermediate contamination levels with accurate EPA/DHA content

Microalgae Oils

Bypass fish bioaccumulation but present different contamination profiles

Neurotoxic Effects of Methylmercury

The toxicity of methylmercury derives from its capacity to interfere with fundamental neurological processes and antioxidant defenses. Mercury exposure generates oxidative stress through reactive oxygen species (ROS) production, mitochondrial dysfunction, and DNA damage [12]. The mechanism involves interaction with intracellular glutathione (GSH) and sulfhydryl groups (R-SH) of critical antioxidant enzymes including superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx), and glutathione reductase (GR). By depleting antioxidant capacity, mercury shifts cellular redox balance toward oxidative stress, initiating cascading effects on cellular signaling, gene expression, protein synthesis, and ultimately cell survival.



At higher exposure levels, mercury interferes with signaling pathways controlling cell growth, proliferation, survival, and metabolism, ultimately triggering apoptotic cell death [12]. The nervous system exhibits particular vulnerability because neurons have limited capacity for regeneration and rely heavily on oxidative metabolism. Mercury also disrupts neurotransmitter systems, particularly those dependent on glutamate, GABA, and monoamines, contributing to behavioral and cognitive dysfunction.

Long-term methylmercury exposure demonstrates association with peripheral neuropathy and cognitive impairment in exposed populations. This evidence demonstrates that chronic, subacute mercury exposure produces measurable neurological dysfunction even in contexts of ongoing exposure.

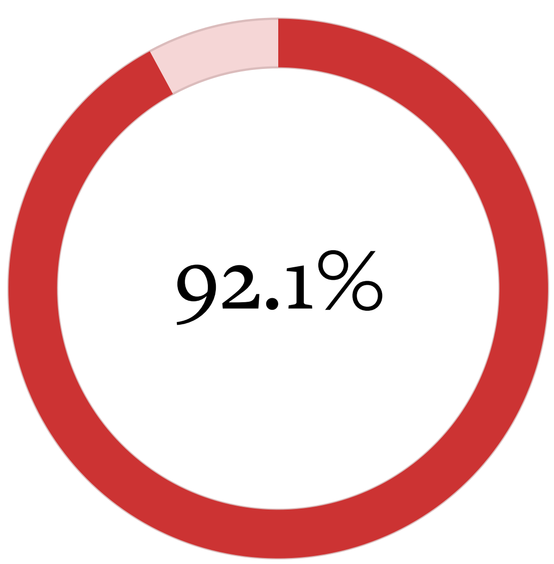
Developmental and Reproductive Effects

Pregnant and lactating women and children represent particularly vulnerable populations for mercury exposure because developmental windows exist during which mercury exposure causes irreversible neurological damage. Methylmercury readily crosses both the blood-brain barrier and the placental barrier, accumulating in fetal brain tissue and achieving concentrations that may exceed maternal levels [1]. Prenatal methylmercury exposure has been associated with impaired motor function, reduced cognitive performance, increased risk of autism spectrum disorders and ADHD, and learning disorders in prospective cohort studies.

> **Fish consumption during pregnancy presents a classic risk-benefit dilemma** because fish provides critical nutrients including omega-3 fatty acids, selenium, iodine, and high-quality protein that support normal fetal development.

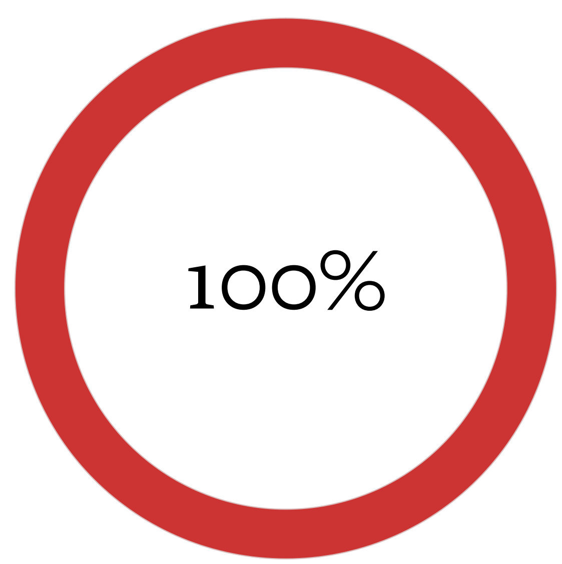
However, large predatory fish and some fish species accumulate methylmercury to concentrations approaching or exceeding regulatory guidance for pregnant women. A large multinational study including pregnant women found that 92.1% consumed fish weekly, with significant associations between fish consumption frequency and improved gestational weight gain and birth weight outcomes [13]. The study concluded that fish consumption should be recommended for pregnant women while emphasizing the importance of limiting exposure to environmental pollutants, with omega-3 supplementation suggested as a means to attain nutritional benefits without mercury risk.

Breastfeeding women may also transfer methylmercury to infants through breast milk, though the evidence suggests that breastfeeding benefits generally outweigh mercury contamination risks if mercury exposure remains modest. Fish oil supplements present a potential avenue to obtain omega-3 fatty acids without the mercury burden of consuming whole fish, though supplement mercury content must be verified through testing or regulatory compliance documentation [1].



Fish Consumption

Pregnant women consuming fish weekly in multinational study



Placental Transfer

Methylmercury crosses placental barrier reaching fetal brain

Biomonitoring and Population-Level Mercury Exposure Assessment

Hair provides a non-invasive biological matrix for biomonitoring methylmercury exposure. Mercury accumulates in hair through binding to sulhydryl groups of hair proteins, with hair methylmercury concentration reflecting integration of methylmercury exposure over approximately the preceding 6-12 months, representing a medium-term exposure window [14]. Hair analysis enables assessment of population-level mercury exposure patterns and identification of subpopulations with elevated exposure warranting intervention.

A standardized high-throughput procedure for biomonitoring methylmercury in human hair using inductively coupled plasma mass spectrometry (ICP-MS) and frontal chromatography was developed and validated to enable large-scale screening [14]. This method achieved limits of detection suitable for analysis of up to 100 samples daily, making it suitable for public health surveillance programs. Application of this method to individuals revealed clear correlation between hair methylmercury levels and fish consumption frequency, validating the approach for dietary exposure assessment.

Children in oil-producing regions of Kazakhstan demonstrate elevated mercury and aluminum in hair samples, with children living closest to oil and gas fields showing the highest mercury concentrations [15]. Mercury levels decreased significantly with increasing distance from industrial facilities, suggesting both occupational and environmental exposure pathways. This environmental pattern underscores that mercury contamination in supplements represents only one of multiple exposure routes, and that total mercury burden reflects cumulative exposure from diverse sources.

1 **Hair Growth Period**
6-12 months of integrated mercury exposure captured in hair sample

2 **Sample Collection**
Non-invasive hair sampling from population groups

3 **ICP-MS Analysis**
High-throughput testing of up to 100 samples daily

4 **Exposure Assessment**
Correlation with dietary patterns and environmental sources

Arctic Populations and Risk Communication

Arctic populations experience among the highest exposure levels to long-range transported contaminants globally, with the primary exposure pathway being dietary consumption of traditional foods including fish and marine mammals. Mercury bioaccumulates through aquatic food chains, and apex marine predators in Arctic waters accumulate particularly high methylmercury concentrations. Current dietary advice in European Arctic countries emphasizes the importance of a nutritious diet while noting specific contaminant-related restrictions.

Risk communication activities in Arctic countries reveal limited information on effectiveness evaluation, with effectiveness data particularly sparse from Arctic countries. This evidence gap concerning risk communication for mercury in traditional and supplemental food sources underscores the need for improved communication strategies and evaluation of their effectiveness in reducing population-level exposure while maintaining nutritional adequacy.

Future Directions and Recommendations

Strengthening Regulatory Oversight and Pre-Market Quality Control

The review of available evidence suggests several priority recommendations for regulatory agencies and supplement manufacturers. First, jurisdictions lacking mandatory pre-market quality control testing should implement requirements for verification of mercury content before supplements reach consumers. The model used by Health Canada and EFSA—requiring quality documentation and sometimes third-party testing—provides a template for other regulatory systems to consider [1].

Second, regulatory harmonization across major jurisdictions would reduce complexity for manufacturers while ensuring consistent safety standards. International Codex standards could be strengthened and made mandatory for internationally traded supplements, with specific provisions for vulnerable populations such as pregnant women, children, and populations with high seafood consumption.

Third, post-market surveillance should be enhanced through systematic monitoring of supplement mercury content, enabling detection of contaminated products and rapid market intervention [1]. Current post-market surveillance in many countries relies on adverse event reporting, which inadequately detects chronic contamination effects.

Alternative Sources and Technological Innovations

The evidence supports increased investigation and development of alternative omega-3 sources, particularly microalgae-derived oils that bypass fish trophic bioaccumulation. Microalgal oils can provide concentrated EPA and DHA equivalent to fish oils without inherent mercury bioaccumulation [10]. However, research on microalgae-based products indicates that these sources present other contamination concerns requiring equivalent regulatory attention [11].

Gene-editing technologies offer potential for enhancing omega-3 PUFA production in aquaculture species while reducing mercury bioaccumulation through selective breeding or genetic modification [2]. However, regulatory approval of gene-edited products varies substantially across jurisdictions, potentially limiting near-term implementation.

Consumer Education and Transparent Labeling

Consumer access to information concerning mercury content of supplements remains limited in most markets. While voluntary third-party testing programs provide some assurance of product quality, these programs remain optional for manufacturers and reach only a subset of marketed supplements.

Transparent labeling requirements specifying mercury content would enable informed consumer choice. Extending such guidance to supplements would require standardized labeling and education initiatives [1].

Mandatory Pre-Market Testing

Implement verification requirements before supplements reach consumers

Regulatory Harmonization

Strengthen international Codex standards for traded supplements

Enhanced Surveillance

Systematic monitoring to detect contaminated products rapidly

Alternative Sources

Develop microalgae-derived oils bypassing fish bioaccumulation

Transparent Labeling

Require mercury content disclosure for informed consumer choice

Conclusion

Mercury contamination in fish oil supplements remains a complex public health issue spanning production, regulation, quality control, and consumer protection. While studies from 2019-2024 consistently demonstrate that most commercial supplements in developed markets comply with regulatory standards, significant gaps persist in mandatory pre-market testing, regulatory harmonization, and post-market surveillance.

Regional variation in mercury content reflects differences in fishing practices, supplement sourcing geography, and local manufacturing standards. European Union oversight provides a comparatively rigorous model, yet even within stringent regulatory frameworks, supplementation with mercury-contaminated fish oil products can incrementally increase population-level methylmercury exposure, particularly among vulnerable groups including pregnant women and children.

Future mitigation strategies should prioritize strengthening pre-market quality control requirements, supporting development of alternative omega-3 sources, and improving consumer access to information concerning mercury content. The resolution of mercury contamination in fish oil supplements will require coordinated international effort, technological innovation, and commitment to transparent, evidence-based regulatory policy protecting public health.

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