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Seafood Consumption and Its Impact on Health: A Narrative Review of Nutritional Benefits and Chemical Contaminant Risks

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KEYWORDS

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ABSTRACT:

Introduction: Seafood provides high-quality protein and essential nutrients and is a key dietary source of long-chain omega-3 fatty acids (eicosapentaenoic acid, EPA; docosahexaenoic acid, DHA). However, seafood can also be a pathway for exposure to chemical contaminants, particularly methylmercury, persistent organic pollutants (dioxins and dioxin-like PCBs), and toxic elements (inorganic arsenic, cadmium, lead).

Objectives: To synthesize evidence on nutritional benefits of seafood consumption and evaluate major seafood-related chemical health risks using benchmark-based risk characterization, highlighting exposure pathways and risk–benefit considerations.

Methods: A narrative evidence synthesis was conducted using PubMed/MEDLINE, Scopus, and Google Scholar, complemented by authoritative sources (FAO, WHO/FAO, EFSA, U.S. FDA/EPA, EPA IRIS, and WHO/JECFA). Searches covered 1 January 2000 to 31 December 2025 (last search: 31 December 2025).

Results: Global aquatic animal foods supply continues to increase, reinforcing seafood's relevance to dietary policy and exposure assessment. Benefits are most consistently reported for cardiometabolic outcomes and neurodevelopmental endpoints linked to EPA/DHA intake. Chemical risks are contaminant- and species-dependent: methylmercury biomagnifies in high-trophic fish, whereas cadmium, lead, and arsenic may be more prominent in selected shellfish categories.

Conclusions: Benefits of seafood can be achieved while reducing chemical risks through species choice, adherence to advisories for vulnerable groups, strengthened monitoring and risk communication. Harmonizing benchmark-derived guidance across agencies remains a critical challenge for coherent public health messaging.

1. Introduction

Seafood (fish and shellfish from marine and freshwater systems) occupies a unique position in public health nutrition: it is simultaneously a vital source of essential nutrients and a significant pathway for exposure to environmental contaminants. This duality creates a persistent tension for consumers, health professionals, and policymakers [1-3].

The nutritional importance of seafood is well-established. It provides high-quality protein, essential micronutrients, and is the primary dietary source of long-chain omega-3 polyunsaturated fatty acids—eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [1]. At the population level, seafood contributes substantially to food and nutrition security. The Food and Agriculture Organization of the United Nations (FAO) reported that 89% of global aquatic animal production was used for human consumption in 2022, equivalent to approximately 20.7 kg per capita [1]. However, this aggregate figure masks substantial heterogeneity in consumption patterns across countries and communities, which has important implications for both nutrient adequacy and contaminant exposure [2,3].

Concurrently, aquatic ecosystems receive persistent pollutants from industrial emissions, mining, wastewater discharge, agricultural runoff, and atmospheric transport, making seafood a vehicle for human exposure to multiple chemical hazards [4-8]. Priority contaminants include methylmercury (MeHg), which biomagnifies through aquatic food webs and is a well-characterized developmental neurotoxicant [4,9,10]; persistent organic pollutants (POPs) such as polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and dioxin-like

polychlorinated biphenyls (dl-PCBs), which accumulate in fatty tissues and exert endocrine-disrupting effects [5,18]; and toxic elements including inorganic arsenic (iAs), cadmium (Cd), and lead (Pb), which exhibit species-specific accumulation patterns and diverse toxicological profiles [4,6-8].

The coexistence of nutritional benefits and chemical risks necessitates integrated evidence synthesis and risk communication. Risk--benefit assessment (RBA) frameworks have emerged as tools to support public health messaging by quantitatively or qualitatively weighing nutrient benefits against contaminant risks under realistic consumption scenarios [11-13]. However, these frameworks face substantial challenges: variability in contaminant occurrence across regions, differences in benchmark values and methodological approaches used by authoritative agencies, and the inherent difficulty of comparing disparate health endpoints (e.g., cardiovascular protection vs. neurodevelopmental toxicity).

2. Objectives

(1) To summarize the nutritional benefits of seafood consumption, focusing on EPA and DHA.

(2) To evaluate major seafood-related chemical health risks (MeHg, dioxins/dl-PCBs, iAs/Cd/Pb) by describing exposure pathways, bioaccumulation/biomagnification, and benchmark-based risk characterization using authoritative agency values.

3. Methods

This narrative review was prepared using key elements of the Scale for the Assessment of Narrative Review Articles (SANRA) to improve clarity of scope, transparency of evidence identification, balanced reasoning, and presentation of outcomes [14]. Searches were conducted in PubMed/MEDLINE, Scopus, and Google Scholar. In addition, authoritative sources were consulted to obtain benchmark toxicity values, contaminant evaluations, and official consumption advisories relevant to seafood-related chemical risks, including FAO, WHO/FAO expert reports, the European Food Safety Authority (EFSA), the U.S. Food and Drug Administration (FDA), the U.S. Environmental Protection Agency (EPA), the EPA Integrated Risk Information System (IRIS), and the WHO Joint FAO/WHO Expert Committee on Food Additives (JECFA).. The search period was 1 January 2000 to 31 December 2025 (last search date: 31 December 2025). Search terms combined seafood exposure and nutritional benefit concepts with chemical hazard concepts (e.g., seafood/fish/shellfish; omega-3/eicosapentaenoic acid/docosahexaenoic acid; methylmercury/mercury; dioxins/dioxin-like PCBs; arsenic/cadmium/lead; exposure; risk assessment; risk–benefit assessment), adapted to each database. English-language peer-reviewed reviews and key studies relevant to seafood nutrition/health outcomes and/or seafood-related chemical exposures were prioritized, together with official agency guidance for benchmark values and advisories. Records not relevant to human dietary exposure or lacking sufficient methodological transparency were excluded. A total of 481 records were identified across all sources, and 25 articles were included in the narrative synthesis.

4. Results

Seafood consumption context

FAO food balance sheets and FishStat consumption statistics provide standardized indicators of "apparent consumption"—supply available at the consumer level rather than individual dietary intake [2,3]. These data reveal substantial geographic variation: per capita seafood consumption ranges from <10 kg/year in some landlocked low-income countries to >50 kg/year in island nations and coastal Asian populations [1-3]. This variation has important implications for both the potential health benefits (greater EPA/DHA intake) and risks (higher contaminant exposure) that different populations may experience.

Nutrient-related health outcomes

Seafood nutrients, especially EPA and DHA, are associated with cardiometabolic benefits and neural development. A 2020 review (Innes & Calder) concludes that marine omega-3 PUFA intake may reduce cardiovascular risk in high-risk populations, though effects vary [15]. Risk–benefit assessments incorporate EPA/DHA intake as benefit endpoints; for example, a Portuguese quantitative risk–benefit assessment compared EPA/DHA-related benefit metrics against methylmercury-related risk under realistic seafood consumption scenarios. [12] An evidence scan of seafood risk–benefit assessment highlights heterogeneity

in endpoints and assumptions and supports transparent characterization of prioritized risks and benefits. [13]

Methylmercury

MeHg originates from environmental mercury that is methylated in aquatic systems. It biomagnifies up the food chain, leading to highest concentrations in top predator fish (e.g., swordfish, tuna) and marine mammals [4,26]. The primary health concern is developmental neurotoxicity. EFSA established a tolerable weekly intake (TWI) for methylmercury of 1.3 µg/kg body weight/week, while WHO/JECFA reports a provisional tolerable weekly intake (PTWI) of 1.6 µg/kg body weight/week. [4,16] EPA IRIS provides an oral reference dose (RfD) for methylmercury of 1×10^{-4} mg/kg-day (0.1 µg/kg-day). [17] U.S. consumer guidance from the Food and Drug Administration and Environmental Protection Agency provides species-based advice intended to reduce methylmercury exposure in pregnancy, breastfeeding, and early childhood. [9,10]

Dioxins and dioxin-like PCBs

PCDD/Fs and dl-PCBs are persistent bioaccumulative pollutants. They accumulate in fatty tissues of fish and marine mammals. WHO uses TEQ (toxic equivalency) to assess cumulative toxicity [5,18]. EFSA's 2018 opinion established a tolerable weekly intake (TWI) of 2 pg WHO-TEQ/kg body weight/week for the sum of dioxins and dl-PCBs in food. [5] WHO/JECFA reports a provisional tolerable monthly intake (PTMI) of 70 pg TEQ/kg body weight/month [18]. EPA IRIS provides a chronic oral reference dose (RfD) for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) of 7×10^{-10} mg/kg-day [19].

Inorganic arsenic, cadmium, and lead

These toxic elements come from natural and anthropogenic sources. In seafood: inorganic arsenic (iAs) is of concern especially in some shellfish and seaweed. For inorganic arsenic, WHO/JECFA withdrew the former PTWI and provides benchmark-dose information; the database summary reports a benchmark dose lower confidence limit for a 0.5% increased risk (BMDL0.5) of 3 µg/kg body weight/day for lung cancer under specified assumptions [20]. EPA IRIS (2025) reports an oral RfD of 0.06 µg/kg-day for inorganic arsenic for noncancer outcomes [21]. EFSA reported a BMDL01 range of 0.3–8 µg/kg body weight/day across endpoints, highlighting the importance of speciation and exposure context [6]. Cadmium can accumulate in certain seafood categories; EFSA established a cadmium TWI of 2.5 µg/kg body weight/week and WHO/JECFA reports a cadmium PTMI of 25 µg/kg body weight/month; EPA IRIS reports an oral cadmium RfD of 0.001 mg/kg-day [7,22,23]. For lead, EFSA concluded the former PTWI was no longer appropriate, WHO/JECFA withdrew the PTWI as not health protective, and EPA IRIS indicates that an oral RfD for inorganic lead is inappropriate given low-threshold effects and complex toxicokinetics [8,24,25].

Table 1. Summary of priority seafood-related chemical hazards, benchmark values, and practical risk-reduction actions.

Contaminant	Main seafood sources (pattern; species/category-dependent)	Health endpoints (high-level)	Guideline limits (WHO/EFSA/EPA)	Mitigation / advisory actions
Methylmercury (MeHg)	Higher in high-trophic predatory fish; biomagnifies	Developmental neurotoxicity (fetus/child), neurologic effects	EFSA TWI 1.3 µg/kg bw/week [4]; WHO/JECFA PTWI 1.6 µg/kg bw/week [16]; EPA IRIS RfD 1×10^{-4} mg/kg-day [17]	Species-based choice and adherence to FDA/EPA guidance for pregnancy/children [9,10]

Contaminant	Main seafood sources (pattern; species/category-dependent)	Health endpoints (high-level)	Guideline limits (WHO/EFSA/EPA)	Mitigation / advisory actions
Dioxins + dioxin-like PCBs (TEQ)	Lipophilic POPs; bioaccumulate; exposure varies by source/fat	Endocrine/immune/reproductive/developmental effects; chronic exposure	EFSA TWI 2 pg WHO-TEQ/kg bw/week [5]; WHO/JECFA PTMI 70 pg TEQ/kg bw/month [18]; EPA IRIS TCDD RfD 7×10^{-10} mg/kg-day [19]	Diversify intake and strengthen monitoring/communication (TEQ-based); provenance matters [5,18,30]
Inorganic arsenic (iAs)	Speciation-dependent; environment- and food-category dependent	Cancer and noncancer outcomes depending on benchmark	WHO/JECFA PTWI withdrawn; BMDL0.5 3 µg/kg bw/day [20]; EPA IRIS RfD 0.06 µg/kg-day [21]; EFSA BMDL01 range 0.3–8 µg/kg bw/day [6]	Emphasize speciation-aware monitoring and transparent benchmark reporting [6,20,21]
Cadmium (Cd)	Often higher in some molluscs/cephalopods; chronic bioaccumulation	Kidney tubular effects; bone effects	EFSA TWI 2.5 µg/kg bw/week [7]; WHO/JECFA PTMI 25 µg/kg bw/month [22]; EPA IRIS RfD 0.001 mg/kg-day [23]	Monitor higher-risk categories; avoid hotspot sourcing; interpret by category/species where data exist [7,22,26]
Lead (Pb)	Variable; possible contributions from environment/processing	Neurodevelopmental and cardiovascular effects; low-threshold concern	EFSA PTWI no longer appropriate [8]; WHO/JECFA PTWI withdrawn [24]; EPA IRIS oral RfD inappropriate [25]	Reduce exposure as low as practicable; protect children/pregnancy; strengthen supply-chain controls [8,24,25]

5. Discussion

This review emphasizes that seafood consumption involves trade-offs between nutritional benefits and contaminant risks.

Species, trophic level, and sourcing shape exposure

Species and trophic level strongly influence contaminant patterns, particularly for methylmercury (MeHg), while lipid content and source environment influence exposure to persistent organic pollutants (POPs) such as polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (dl-PCBs) [4,5,18,26]. Biomagnification of MeHg through aquatic food webs explains why some top-trophic species contribute disproportionately to dietary exposure and underpins the logic of species-based dietary advice in several national guidelines [4,9,10,26]. For POPs, the TEQ framework is used to integrate toxicity across congeners and support cumulative risk characterization; EFSA and WHO/JECFA have emphasized the role of diet (including animal-derived foods such as fish and seafood) as a key exposure pathway [5,18,30]. For toxic elements, evidence from recent global synthesis indicates that profiles can be more category- and species-dependent than MeHg, with variability across finfish, molluscs, and cephalopods, supporting category-specific interpretation rather than generalized avoidance of seafood [26].

Benefits are credible but context-dependent

Nutritional benefits of seafood are supported by mechanistic plausibility and clinical evidence, particularly for long-chain omega-3 fatty acids (eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]) and cardiometabolic outcomes [15]. Recent meta-analyses of cohort studies also support associations between fish intake (fatty or lean) and reduced cardiovascular disease outcomes and/or mortality, although effect size and dose–response patterns vary across populations and exposure contexts [27,28]. However, the presence of chemical hazards means that benefit messaging should not be separated from chemical safety; rather, benefits are best achieved by maintaining seafood intake while applying contaminant-aware species selection and sourcing considerations [9–11,13,16,17,26].

Pregnancy and early life remain the central risk–benefit tension

Pregnancy and early childhood are critical windows because neurodevelopment is a key endpoint both for nutritional benefit (adequate DHA intake) and for MeHg toxicity. EFSA benchmark values and FDA/EPA consumer advice explicitly prioritize these sensitive groups, providing species-based guidance intended to reduce mercury exposure while supporting continued seafood consumption [4,9,16,17]. Risk–benefit assessment (RBA) approaches provide a structured way to address this tension by jointly evaluating nutritional endpoints (e.g., EPA/DHA intake) and contaminant endpoints (e.g., MeHg exposure) under realistic consumption scenarios [11–13]. Recent pregnancy-focused RBA work similarly demonstrates that risk–benefit conclusions depend on species patterns, contaminant levels, and assumed intake scenarios, reinforcing the importance of species-specific advice rather than blanket reduction of seafood intake [29].

Benchmark values guide risk characterization and communication

Benchmark values from EFSA, WHO/JECFA, and EPA IRIS provide essential context for chemical risk characterization and for interpreting surveillance results (Table 1) [4–8,16–25]. Differences across agencies reflect differences in endpoints and averaging periods. For example, EFSA expresses tolerable intake for MeHg and for dioxins/dl-PCBs as weekly tolerable intakes, WHO/JECFA also reports monthly tolerable intake for TEQ-based POPs, and EPA IRIS provides chronic reference doses in mg/kg-day [4,5,16–19]. For arsenic, the coexistence of benchmark-dose approaches for cancer endpoints and reference dose approaches for noncancer endpoints illustrates that numerical values may differ depending on the chosen endpoint and method, requiring transparent reporting of the benchmark used and its units [6,20,21]. In practice, effective risk communication should explicitly identify whether a message is grounded in EFSA TWIs, WHO/JECFA PTWIs/PTMIs, or EPA IRIS RfDs to reduce misinterpretation when translating benchmark values into serving-based advice [4,5,16–21].

Monitoring priorities and public health implications

From a public health perspective, the evidence supports an integrated approach to seafood guidance: maintain nutrient benefits while minimizing chemical risks through routine monitoring, transparent reporting, and targeted consumer advice for sensitive groups [4–11,16–25]. WHO/FAO emphasizes risk–benefit framing for fish consumption as a foundation for public messaging, especially when addressing pregnancy and early life [11]. For POPs, reviews across animal-derived foods—including fish and seafood—underscore the importance of continued surveillance and exposure reduction strategies where monitoring indicates higher levels, consistent with the cumulative nature of TEQ-based risk characterization [5,18,30]. Overall, the most defensible policy direction is not generalized avoidance of seafood, but rather contaminant-aware species selection, dietary variety, and clear guidance tailored to vulnerable groups, supported by benchmark-based risk characterization and monitoring systems [9–13,16–19,26–30]

Limitations and evidence gaps

As a narrative review, this synthesis does not provide pooled quantitative estimates of effect size. Additional gaps include limited comparability of contaminant occurrence across regions due to differences in monitoring designs, evolving analytical speciation (especially for arsenic), and variable implementation of advisories and labeling. Methodological heterogeneity in seafood RBAs remains a known challenge, underscoring the need for standardized prioritization and uncertainty reporting [12,13,29]. Emerging issues like microplastics are noted but not covered here due to evolving evidence.

In summary, seafood remains an important contributor to sustainable diets and nutrition security, with global supply and per-capita contribution continuing to increase. The health impact of seafood depends on informed choices and regulatory oversight. Public health messages should emphasize consumption of fish lower in contaminants (especially for pregnant women and children), support routine monitoring of seafood safety, and clearly explain which benchmarks are being used. When these steps are taken, seafood's benefits for health can be largely achieved while keeping chemical risks at acceptable levels.

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