HEAVY METAL PARAMETERS FOR SHELLFISH					
Measured Parameter (Symbol) Unit	Midwest Lab Report Limit[†, 12]	Saltwater (35 ppt) Composition[8]	FDA Action Level[*,5]	Removal	Comments
Arsenic (As) mg/L	0.0005	0.0026	86.0	• Biological filtration • Biosorption removal (94%) with powdered raw avocado seed [4]	• High accumulation by marine organisms is well-known natural phenomenon [9] • EDTA may increase bioavailability, lowering healthy D-larvae yields [10]
Barium (Ba) mg/L	0.005	0.021		• Precipitation, metal chelators, ion exchange, coagulation, flocculation, and biological processes such as microbial metal uptake [16]	• Normal embryonic development can be inhibited in mussels and sea urchins at ~200 ppb [3]
Cadmium (Cd) mg/L	0.002	0.00011	4.0	• Addition of 1 mg/mL EDTA (metal chelator) improved survival of D-larvae blue mussels [10]	• Retail manila clams contained <0.5 ug/g of meat, below international safety guidelines of 2 µg/g wet weight [19] • Levels of cadmium tend to be higher in Pacific Ocean than Atlantic due to a "conveyor belt system" • Levels relatively higher in oysters and shrimp, moder-ately high in scallops and squids, less in clams [20]
Chromium (Cr) mg/L	0.01	0.0002	13.0	• Addition of 1 mg/mL EDTA improved survival of D-larvae blue mussels [10]	• Pearlshell mussel (1-week post-set) successfully cultured and tested in acute 96 h Cr exposures (919 µg/L EC50) [21] • Elevated temperature increased acute toxicity
Copper (Cu) mg/L	0.01	0.0009		• Using L-threonine-modified palygorskite [4] • Addition of 1 mg/mL EDTA improved survival of D-larvae blue mussels [10]	• *Venerupis decussata* (carpet shell)*:* 0.1 mg/L resulted in 100% mortality after 50 days [16] • *Cupric chloride:* Oyster larvae - 32.8 ppb for 50% mortality and 56 ppb for 95% mortality; Clam larvae - 11.7-16.4 ppb [7] for 50% mortality and 28 ppb for 95% mortality [2] • *Copper sulfate:* 0.7-1 mg/L used to control algae and some pathogens [6] • Algae can concentrate copper; ingesting copper- containing *Isochrysis galbana* was a source of toxicity for larval clams [7] • Affected by dissolved organic matter, alkalinity, pH, age and size of organism, feed, acclimation time [6]

Measured Parameter (Symbol) Unit	Midwest Lab Report Limit[†, 12]	Saltwater (35 ppt) Composition[8]	FDA Action Level[*,5]	Removal	Comments
Iron (Fe) ppm	0.05	0.0034		• Filtration after oxidation with air, potassium permanganate, or chlorine [17]	• Shrimp: >20 mg/L can lead to iron hydroxide formation. Precipitate can settle on eggs and damage or kill them [1] • Blue mussel: Toxic shellfish levels are not known. Oxidative stress caused by iron could contribute to reduced embryo survival rates [11]
Lead (Pb) mg/L	0.0005	0.00003	1.7	• Adsorption: *Eucalyptus globulus* leaf powder • Addition of 1 mg/mL EDTA improved survival of D-larvae blue mussels [10] • EDDS (biodegradable metal chelator) at concentrations of 3 and 12 µM works as effectively as EDTA [11]	• Black clams: chronic toxicity value of 0.64 mg/L. Concentrations of 10 and 100 µg/L induced cellular damage. Pb content decreased at the end of the depuration period (14 days) by 1.7% and 41% in the gills and 59% and 39% in the digestive gland [14]
Mercury (Hg) mg/L	0.0004	0.00015	1.0	• Coagulation/filtration, granulated activated carbon, lime softening [15]	• *Mercuric chloride*: Oyster larvae - 12.0 ppb for 50% and 20.7 ppb for 95% mortalities; Clam larvae - 14.7 ppb for 50% and 25.4 ppb for 95% mortalities [2] • EDTA may increase bioavailability, lowering healthy D-larvae yields [10]
Nickel (Ni) mg/L	0.01	0.0066	80.0	• Precipitation, metal chelators, ion exchange, coagulation, flocculation; and biological processes such as microbial metal uptake [16]	• *Nickle chloride*: Oyster larvae - 1,200 ppb for 50% and 2,500 ppb for 95% mortalities; Clam larvae - 4,700 ppb for 50% and 10,300 ppb for 95% mortalities [2]
Thallium (Tl) mg/L	0.0005		80.0	• Precipitation, metal chelators, ion exchange, coagulation, flocculation; and biological processes such as microbial metal uptake [16]	• No data available on the accumulation in shellfish [18]
Zinc (Zn) ppm	0.01	0.005		• Addition of 1 mg mL/ EDTA improved survival of D-larvae blue mussels [10] • EDDS at concentrations of 3 - 12 µM works as effectively as non-degradable EDTA [11]	• *Zinc chloride*: Clam larvae - 195 ppb for 50% and 341 ppb for 95% mortalities [2] • Zinc is a vital metal for several biological processes including shell formation, but can be toxic for mussels in high concentration [13]

† The smallest amount or lowest concentration of a substance that Midwest Laboratories can determine following established EPA analytical procedures.

* Action levels represent limits at or above which the US Food & Drug Administration (FDA) will take legal action to remove adulterated products, including shellfish, from the market. Established based on the unavoidability of the poisonous or deleterious substance and do not represent permissible levels of contamination where it is avoidable.

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ADDITIONAL RESOURCES

Consumer Confidence and Safety

Farrell, Hazel, et al. (2018) An assessment of potential heavy metal contaminants in bivalve shellfish from aquaculture zones along the coast of New South Wales, Australia. *Food Protection Trends* 38.1: 18-26.

Case Studies

Chesapeake Bay: Di Giulio, Richard T., and Patrick F. Scanlon. (1985) Heavy metals in aquatic plants, clams, and sediments from the Chesapeake Bay, USA Implications for waterfowl. *Science of the total environment* 41.3: 259-274.

New Zealand: McDougall, Daniel R., Trevyn A. Toone, and Andrew G. Jeffs. (2022) Natural heavy metal concentrations in seawater as a possible cause of low survival of larval mussels. *Journal of Trace Elements in Medicine and Biology* 74: 127071.

Spain: Franco, Javier, et al. (2002) Heavy metals in molluscs from the Basque Coast (Northern Spain): results from an 11-year monitoring program. *Marine Pollution Bulletin* 44.9: 973-976.