

2012

# Marine Mercury Fate: From Sources to Seafood Consumers

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## Recommended Citation

Chen, Celia Y., Driscoll, Charles T., Lambert, Kathleen F., Mason, Robert P., Rardin, Laurie R., Serrell, Nancy, & Sunderland, Elsie M. (2012). Marine mercury fate: From sources to seafood consumers. *Environmental Research*, 119(0), 1-2. doi: <http://dx.doi.org/10.1016/j.envres.2012.10.001>

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1 **EDITORIAL: Marine mercury fate: from sources to seafood consumers**

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29 Mercury in the biosphere has markedly increased over the past century leading  
30 governments around the world to consider policies that would reduce sources to  
31 limit human exposure to this global contaminant. The nine articles in this issue  
32 provide a synthesis of the science on the sources, fate, and human exposure to  
33 mercury (Hg) in marine systems. These papers along with two papers recently  
34 published in *Environmental Health Perspectives* are the products of two  
35 workshops convened by the Coastal and Marine Mercury Ecosystem Research  
36 Collaborative (C-MERC) sponsored by the Dartmouth Superfund Research  
37 Program. In September 2010 and July 2011 we brought together scientists and  
38 policy stakeholders to compile and distill information on the inputs, cycling and  
39 uptake of Hg in marine ecosystems and the links to fish, wildlife and human  
40 exposure to methylmercury (MeHg), the most bioaccumulative form of this global  
41 contaminant. The goal of this C-MERC effort was to provide a summary of the  
42 current science relevant to public policies being considered at the regional,  
43 national and global level, such as the effort of the United Nations Environment  
44 Programme to establish the first International Mercury Treaty.

45

46 Seven papers in this special issue review the pathways and transformations of  
47 Hg and MeHg from sources to seafood consumers in specific marine  
48 ecosystems. These include: the Gulf of Maine (Sunderland et al. 2012),;the Gulf  
49 of Mexico (Harris et al. 2012a, b); San Francisco Bay (Davis et al. 2012); the  
50 Arctic Ocean (Kirk et al. 2012),;Tropical Oceans (Costa et al. 2012); and the  
51 global oceans (Mason et al. 2012 ). The paper by Driscoll et al. (2012) presents a

52 conceptual model of interactions between Hg cycling and nutrient loading in  
53 marine ecosystems and the paper by Lambert et al. (2012) provides a review of  
54 Hg science on marine ecosystems and implications for policy. The C-MERC  
55 papers published in *Environmental Health Perspectives* focused on human  
56 health effects of low level methylmercury (MeHg) exposure (Karagas et al. 2012)  
57 and on the complexities of providing clear, unified fish consumption advice (Oken  
58 et al. 2012).

59

60 Coal burning and energy production along with mining and industrial activities  
61 have led to increased mercury in the environment (Mason et al. 1994; Driscoll et  
62 al. 2007; Selin et al. 2008). Mercury is ranked third on the Agency for Toxic  
63 Substances and Disease Registry's priority list of contaminants that pose  
64 significant human health threats to the U.S. population (ATSDR 2007). More than  
65 90 percent of Hg exposure in the U.S. comes from consumption of estuarine and  
66 marine fish contaminated by MeHg, the most bioavailable form (Sunderland  
67 2007; Chen et al. 2008). This exposure is the result of consuming higher trophic  
68 level fish, which generally have higher MeHg concentrations, in combination with  
69 more frequently eaten lower trophic level species (e.g., pollock, crabs, shrimp).  
70 Due to this widespread human exposure, all 50 U.S. states have established fish  
71 consumption advisories for Hg, and most U.S. coastal states on the Atlantic  
72 Ocean have statewide coastal advisories (USEPA 2008; Schmeltz et al. 2011).  
73 Though most people in the U.S. are exposed to MeHg through consumption of  
74 open ocean fish, coastal populations have higher exposure through

75 local/subsistence consumption of regional coastal fisheries.

76

77 Ocean systems included in this special issue represent a broad range of  
78 management challenges for MeHg contamination due to 1) physical  
79 characteristics, 2) dominant Hg sources and MeHg inputs, and 3) different  
80 human fish consumption patterns. The relative contribution of different sources  
81 of Hg (direct atmospheric inputs, watershed inputs, and exchange at the ocean  
82 system boundaries) varies greatly but tends to scale with ocean system size; the  
83 larger the water surface area, the more significant are direct atmospheric sources  
84 and *in situ* water column production of MeHg, and the less dominant are  
85 watershed and coastal point sources.

86

87 Offshore Hg concentrations in open ocean fish are determined by direct  
88 atmospheric inputs, which are transferred via lateral currents to sites of Hg  
89 methylation. As a result, MeHg levels in open ocean fish reflect atmospheric  
90 deposition on a global scale (Mason et al. 2012, this issue). Modeling studies and  
91 measurements suggest that while Hg in the open oceans and MeHg in ocean fish  
92 will decrease immediately in response to decreases in atmospheric emissions it  
93 will take many decades for these reductions to be fully realized. These declines  
94 will benefit the general population of fish consumers who tend to eat grocery  
95 store fish harvested from the open ocean (e.g., canned tuna).

96

97 Marine inshore Hg levels are primarily influenced by coastal and watershed  
98 inputs (e.g., point source discharges, legacy contamination, and indirect  
99 atmospheric inputs). However, there are also substantial differences across  
100 coastal regions in their ability to convert inorganic Hg to MeHg. Hg  
101 concentrations of fish in coastal waters have been shown to respond in the short  
102 term to control of local Hg discharges which are methylated in coastal sediments.  
103 Coastal monitoring data suggest that the measurable impacts on fish MeHg  
104 concentrations will yield benefits to local fishers who consume recreationally  
105 caught fish from adjacent coastal waters (Sunderland et al. 2012, this issue).  
106

107 Hg fate and bioavailability in marine systems and associated human exposure  
108 are also affected by confounding factors such as nutrients and climate change. A  
109 conceptual model testing for interactions of nitrogen inputs and Hg bioavailability  
110 indicates that increased nutrient concentrations relate to decreased Hg and  
111 MeHg in marine organisms (Driscoll et al. 2012, this issue). Climate change will  
112 also alter marine ecosystems in ways that will influence Hg fate but these  
113 impacts are not yet fully understood. Melting sea ice in the Arctic will alter food  
114 webs and mercury biomagnification by forcing animals such as Arctic cod that  
115 normally live beneath the ice to feed instead in surface waters where mercury is  
116 more available (Kirk et al. 2012, this issue). Changes in ocean temperatures will  
117 also alter zones of MeHg production in the open ocean as well as ocean currents  
118 that transport Hg between ocean basins. These confounding factors suggest  
119 that need for greater attention and resources for mercury monitoring in coastal

120 and marine systems in order to accurately assess the efficacy of national and  
121 international policy and associated declines in Hg inputs (Evers et al. 2008;  
122 Lambert et al. 2012).

123

124 Scientific research on Hg fate, and MeHg production and bioaccumulation has  
125 had an important role in informing and motivating policy. However, a number of  
126 challenges particular to MeHg fate and transport in marine systems have  
127 hindered progress in the policy arena (Lambert et al. 2012). These challenges  
128 will benefit from a strong international agreement that addresses: the  
129 transboundary nature of Hg including an emphasis on atmospheric emissions;  
130 expanded cost benefit analyses that account for the human and ecological health  
131 effects of MeHg,;investment in management trials for mitigating the on-going  
132 contamination of legacy sources; and a comprehensive and integrated global  
133 mercury monitoring network with periodic assessments (Lambert et al. 2012).

134

135 Current research indicates that mercury contamination of marine systems has  
136 important implications for human health. Fortunately, as policy makers gather to  
137 discuss remedies at all scales of government, a large body of mercury research  
138 can inform their decision-making. This special issue on mercury in marine  
139 ecosystems is the product of a group of scientists and stakeholders who  
140 participated in the C-MERC effort to bring science to the policy table.

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